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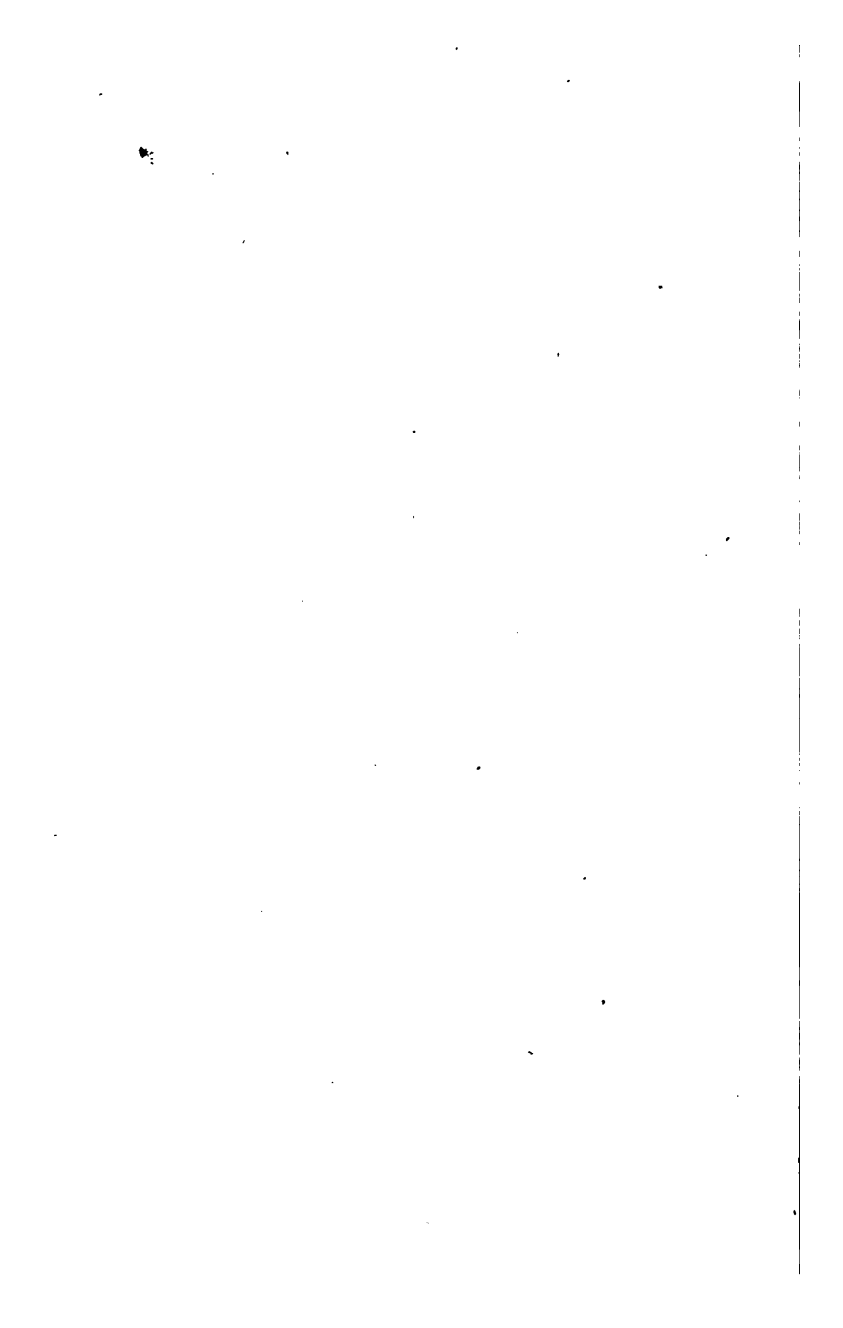
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HOUSEHOLD CHEMISTRY;
OR,
RUDIMENTS OF THE SCIENCE
APPLIED TO
EVERY-DAY LIFE.

BY
ALBERT J. BERNAYS, F.C.S.,
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TO
THE REV. L. J. BERNAYS, M.A.
THIS LITTLE WORK,
CONTAINING
THE SUBSTANCE OF LECTURES DELIVERED AT ELSTREE SCHOOL,
Is Dedicated,
WITH MUCH AFFECTION, BY
HIS BROTHER.

PREFACE.

THE favor with which this little volume has been received by the periodical press, and the rapidity with which the first edition has been sold, relieve me of the necessity of apologising for its re-publication. To make it, however, more worthy of a kind reception, I have not only thoroughly revised it, but re-arranged it in many parts, and made such additions as to render it more useful to the tyro in chemistry. To increase its suitableness as a school-book, I have added questions to the end of every chapter. Still I repeat, that I do not offer it as a class-book to regular students of Chemistry. For such, the excellent introductions by Graham, Fownes, Brande, Liebig, Turner, Gmelin, &c., are all-sufficient. I have written chiefly for the young, and for those who, although people of general education, witness in the processes of daily life some of the most important

chemical operations in themselves, and all that is done for their subsistence, without either knowing or heeding those great laws by which the Author of the Universe has produced and sustains His creation. To such, it was thought, an explanation of these chemical phenomena, in a familiar form, such as is usually adopted in lectures, would prove most advantageous. It might explain and clear up many things, remove many errors, and often supply hints for doing some things better and more effectually than they are usually performed, or remedies in cases of failures or accidents, which otherwise might prove injurious or even dangerous ; and, here and there, encourage men or women of sufficient talent and leisure to enter upon the serious study of a science, which offers such an abundance of amusement and instruction.

I have naturally availed myself of the labors of my predecessors and cotemporaries, as every one does, and must do, when he attempts to write on any science. I have even gone so far as to make use of the very words of others, if I thought I could gain nothing in precision and clearness in employing expressions of my own. I have, however, not failed to acknow-

ledge the sources from which I have thus drawn, except in cases where the words had engraven themselves on my memory with the facts they had taught me, without my being able to remember the original mind to which I may be indebted for both. Whoever knows the works of some of our English Chemical writers, and, at the same time, those of the Germans, will understand what I mean.

The titles of the several chapters are in imitation of Professor Liebig's "Chemistry of Food;" for, as far as I remember, I first thought of lectures under such titles after reading that beautiful work. When I first delivered the lecture on the "Chemistry of Breakfast," some five years ago, the idea was suggested to me by the book just alluded to. The other chapters which make up "Household Chemistry" follow of necessity from the previous thought.

The name "Household Chemistry" was suggested to me by a clergyman, whose knowledge is only exceeded by his goodness, and whose friendship I have the honor to enjoy. The term was, no doubt, suggested by that admirable periodical, "Household Words," a serial worthy of the attention of young and old.

The Appendix contains a number of useful and simple experiments, many of which may be understood and performed by a child of eight years old.

To those who, by the perusal of this book, may be induced to become students of Chemistry, I would recommend the Manual of Fownes. It is compact and accurate, and contains an immense amount of well-digested information.

In conclusion, I would add one word of caution. I should be sorry in any way to encourage a mere smattering of knowledge; but the experimental parts of Chemistry are so striking, that there is danger of their fixing the attention, to the exclusion of any consideration of the relations which subsist between the phenomena. It were as profitable to witness a display of fireworks as thus to attend to chemical experiments. The penalty of the sweat of the brow is as much exacted for the enjoyment of knowledge as of that of the fruits of the field.

CHEMICAL LABORATORY, DERBY,
September, 1852.

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CHAPTER I.

CHEMISTRY OF THE ATMOSPHERE.

THE most intimate relations exist between the constituents of atmospheric air, and those of plants and animals ; so intimate, indeed, that an intelligent knowledge of the varied properties of the air will enable us to understand a host of the phenomena which cross our daily path. By far the greater bulk of substances constituting the vegetable kingdom, such as water, starch, sugar, wood, gum, the various oils so remarkable for their odours, and the resins, are contained, in an elementary form, in the atmosphere. In the animal kingdom, also, with the exception of the bones, and the small portions of earthy matters pervading every liquid and solid part of the frame, we find nothing which is not discoverable in another form in the atmosphere. The very life of plants and animals depends upon air, and the wholesomeness of the latter, upon the relations existing between the animal and vegetable kingdoms.

The AIR is, of itself, colourless, but in the mass has a blue appearance; for it is supposed to absorb the red and yellow, and to reflect the blue rays of the sun; so that its colour is owing to reflected light. At great heights the sky appears of a deeper blue, being mixed with black, owing to the absence of white reflecting clouds.

The atmosphere is limited in extent; but whether from cold, or from a limit to the expansibility of its particles, is not well ascertained. It is, however, supposed to extend, in a state of perceptible density, to a height of nearly forty-five miles.

It is as much a material substance as iron or water. The weight of one hundred cubic inches of air, at the ordinary temperature and pressure, has been computed at thirty grains and three quarters. Temperature is ascertained by an instrument called a *Thermometer*. It is derived from two Greek words θερμός (thermos) heat, and μετρέω (metreo) I measure. It does not show how much heat a body contains; but it points out a difference in the heat of various bodies. The thermometer gives the same kind of information which may be discovered by the feelings, viz.: the impression of heat or cold. All, therefore, that we learn from this instrument is, whether the temperature of one body is greater or less than that of another; and the difference is expressed by the *degrees* of the thermometer. The latter consists of a tube of a uniform small bore,

having a ball blown at one end. The ball and part of the tube are filled with quicksilver (or sometimes spirits of wine), the air is expelled by boiling and then the tube is closed. To obtain the degrees, two fixed points are required, the boiling and freezing of water. The distance between these two points may be divided into any number of equal parts or degrees. Fahrenheit, a philosophical instrument maker, whose scale is commonly used, divided it into 180 degrees, beginning his scale at a point 32 of these degrees below the freezing-point of water, which is the *zero* of the scale. In France, the centigrade thermometer of Celsius prevails. He placed his zero at the freezing-point of water, and divided the distance between that and the boiling point into 100 degrees, whence the name centigrade. Reaumur, whose thermometer is employed in Germany, adopted the same starting-point or zero as did Celsius, but divided the distance between the boiling and freezing of water into 80 degrees only. Thus, the boiling-point of water on Fahrenheit's scale is 212, on the centigrade 100, and on that of Reaumur 80. In order to compare these thermometers with each other, it need only be remembered that 4 degrees of Reaumur are equal to 5 of Celsius and 9 of Fahrenheit. To express *degrees*, the sign ° is employed, to all above 0° or zero, the sign + is usually prefixed; to those below 0°, the sign — is invariably. The ordinary temperature of the air is 60° F.

It may therefore be easily imagined with what force the atmosphere presses upon all bodies. In accordance with the general law of fluids exerting pressure equally in all directions, the weight of the air is not usually felt. But were it not for this law, the weight of the air would be sufficient to crush us. As a familiar illustration, may be instanced a walk in a clay-field on a wet day. The difficulty of lifting the foot is entirely owing to the pressure of the air from above. This pressure is, in round numbers, equal to fifteen pounds upon each square inch of surface.

Atmospheric pressure is exerted upon everything on the earth's surface. If a glass tube, closed at one end, be partly filled with water, and inverted in a basin also filled with water, the fluid will not fall in the tube, but remain suspended at a much higher level than that of the water in the basin. This is owing to the pressure of the air upon the water in the basin; for, if the tube were perforated at the top, the pressure of the air would be exerted equally on the water in the tube and in the basin, and accordingly the water would fall to the same level. If the tube be of any length under thirty-three feet, filled with water and inverted, the pressure of the air upon the water in the basin will be sufficient to keep the tube full.

If the air be exhausted from the tube by means of the air-pump, and the open end then placed under

water, the water will be found to rush with violence up the tube, and so fill it. At the height of thirty-three feet, the column of water becomes balanced by the pressure of the atmosphere ; any change in the pressure of which must, of course, be attended by a change in the height of the column of water. Such an instrument becomes therefore a *measurer of atmospheric pressure*—a *Barometer*, from *βαρος* (baros) weight, and *μετρον* (metron) a measure. Water barometers (an example of which may be seen in the Hall of the Royal Society's rooms) are inconvenient, in consequence of their length. If we can therefore find a heavy liquid to replace the water, the tube need not be so long. Now *quicksilver*, or *mercury*, happens to be thirteen and a half times heavier than water; the tube therefore requires to be but $1-13\frac{1}{2}$ the length. A column of mercury, thirty inches in height, exactly counterbalances the average pressure of a column of air of equal diameter ; or, in other words, the air presses upon the earth with a force equal to that of a layer of quicksilver 30 inches deep. The vacant space above the quicksilver, in the closed end of the barometer-tube, is called the *Torricellian vacuum*, from its having been observed by Torricelli to be free from air.

There are several modifications of the barometer; their action, however, is much the same as that which I have just described.

Though not strictly connected with the subject in

hand, I may here say a few words about the barometer as a weather-glass. East and north winds usually cause the glass to rise; south and west to fall. The first named are cooler, as they come from cold regions; and drier, because they pass over continents: while the latter come from warm regions into colder, and thus they lose some of their capacity for water, but as they pass over vast seas, they again attract much moisture. It therefore rains less frequently with north and east winds than with south and west. Wet and stormy weather is preceded by a fall of the mercury; fair and calm, by a rise.

As might be expected, the air is both tasteless and inodorous: were it otherwise, our sense of taste and smell would be useless.

Atmospheric air consists of a mixture of several gases. According to the latest experiments, one hundred volumes of air are found to contain twenty-one volumes of *Oxygen*—so called from two Greek words, ὄξυς (oxus) acid, and γεννάω (gennao), I produce, because formerly supposed to be the only acidifying principle. This gas is most abundantly diffused throughout nature, forming as much as eight-ninths of the weight of water, one-fifth of the weight of air, and nearly one-half of the weight of the solid rocks which constitute our globe. It is also largely contained in all animal and vegetable substances. Of the importance of oxygen too high

an idea can scarcely be conceived. Neither respiration nor combustion can be carried on without it; in its absence no human being or animal can live, no candle or fire can burn. On these accounts oxygen is also called *Vital air*, from *vita*, life; and *Empyreal air*, from *εν* (en) in, and *πυρ* (pyr) fire. Water, also, absorbs it; hence oxygen is always found in rain, snow, spring, and river water. The oxygen contained in rain, as it trickles through the soil, ministers to the growth and nourishment of plants in various ways. It exerts a very powerful influence upon some of the constituents of the soil, rendering them soluble in water, and is the cause of the decay and putrefaction of vegetables. It has neither colour, taste, nor smell; its specific gravity is greater than that of air, being as 1.111 to 1.000. It is always gaseous, when not combined with other matters. It does not change the colour of flowers. Itself an element*, oxygen possesses most powerful attractions for other bodies. When a substance unites with oxygen it is said to *oxydize*; the act of combination is called *oxydation*. Oxydized bodies are divided into two classes: acids and oxides. The former division includes those compounds which possess the general properties of acids; and the

* The term element is applied to such forms of matter as have hitherto resisted all efforts to decompose them, or to separate them into forms of matter possessed of different properties.

latter comprehends those which not only do not possess that character, but of which many are highly alkaline, and yield salts by uniting with acids.

Mixed with the vital air, the atmosphere is found to contain, in one hundred volumes, seventy-nine volumes of another gas, called *Azote* or *Nitrogen*. The name azote (from α , privative, and $\zeta\omega\eta$, zoe, life), was given to it on account of its inability to support life; and it was called nitrogen, as being a constituent part of nitric acid. Like oxygen, it has neither colour, taste, nor smell; but it does not support respiration or combustion. It is rather lighter than atmospheric air, compared with which its specific gravity is as 0.972 to 1.000. It has no action upon vegetable colours. All attempts to decompose it having failed, it must be considered to be an element. It is a constituent of many vegetable and of most animal substances; indeed, no kind of food can be considered nutritive, or, at least, capable of forming flesh and blood, unless nitrogen forms a portion of it. Although it will not support respiration, the fact of its forming so large a portion of the air, proves its harmlessness. We are doubtless unacquainted with many of its uses, but we know that its presence in the atmosphere is essential to temper the effects of oxygen upon the system. Pure oxygen, if inhaled by a human being or an animal for any length of time, will cause inflammation, and ultimately, death.

Nitrogen manifests so few and such feeble attractions or affinities towards oxygen and other bodies, that it is eminently adapted for admixture with other gases.

Another important constituent of the atmosphere, although, however, very small in amount, is *Carbonic acid*, called also fixed air, or choke-damp. According to the most recent experiments, one hundred volumes of inland air, contain, on an average, 0.05 volumes of carbonic acid gas. The air on mountains contains more carbonic acid than that of low lands, probably because in the higher regions the air meets with fewer plants, and the carbonic acid is less likely to be absorbed by moisture. The maximum quantity of carbonic acid in the atmosphere is found towards morning ; the minimum, at the close of day. Its sources are very numerous. At every respiration of men and animals, a portion of the *Carbon* of the blood unites with the oxygen of the air, and forms carbonic acid. The combustion of wood and coal, the processes of decay, fermentation, and putrefaction, are largely productive of this gas. Whenever carbon unites with oxygen at high temperatures, carbonic acid is always the result.

This constituent of the atmosphere is, then, a compound body—a compound of oxygen with another element. That rare and beautiful gem, the *diamond*, consists of pure carbon. It crystallizes in

octohedrons; is generally colourless and transparent, of greater hardness than any other known substance, peculiarly lustrous, and, like oxygen and nitrogen, a non-conductor of electricity. Heated to redness in an atmosphere of pure oxygen, the diamond burns quickly away, unites with oxygen, and forms carbonic acid. *Plumbago* is also a species of carbon. It is so soft, and imparts its colour so readily to other bodies, that it is used in making lead pencils, whence its other name, *graphite*, from the Greek, *γραφειν* (*graphein*), to write. From its similarity to lead, and the black polish it gives to stoves, it is also called *black lead*. But, besides these two forms of it, carbon is to be met with in a state of great abundance both in the animal and vegetable kingdom. Coal and coke consist mainly of carbon; indeed, it is to be found in nearly all the materials employed in the production of artificial light and heat.

For the purpose of forming an idea of the quantity of carbonic acid given off to the air in a single place, it may be mentioned that in London and its suburbs two million tons of coal are annually consumed, the combustion of which requires upwards of four million tons of oxygen, which must be provided by the atmosphere. To this carbonic acid, resulting from the union of the coal with oxygen, must be added that produced by the burning of so many gas-lights, candles, &c. Again, there are congregated in the metropolis upwards of two million

of human beings, each of whom will, on an average, daily supply four pounds of carbonic acid to the atmosphere; and if to this be added the production of this gas from horses and other animals, and from the processes of fermentation in breweries and distilleries, it will appear that London alone supplies the enormous quantity of eleven millions of tons annually to the atmosphere.

Carbonic acid, then, is of very frequent occurrence. At ordinary temperatures it is a colourless gas, incombustible, and does not support the combustion of most other bodies. Although one of the weakest acids, it communicates a red colour to blue litmus paper, and combines with oxides, forming a class of salts called *carbonates*. Thus, for example, it has great affinity for lime, with which it readily combines, and forms carbonate of lime. It has a slightly irritating odour; and when inhaled pure, or even largely admixed with air, it causes death. Water, at ordinary temperature, absorbs its own volume of this gas, but much more under pressure. Upon this principle soda-water is made, which consists simply of water into which carbonic acid is forced by pressure. What is usually termed effervescence (from *effervescens*, boiling), is produced by the rapid escape of this gas, as in champagne, ginger-beer, ale, and porter. Its specific gravity is far greater than that of air, being as 1.525 to 1000. It is therefore liable to accumulate in holes and

caves of the earth, and even in rooms not properly ventilated. In close rooms the oxygen of the air is, by the process of respiration, converted into carbonic acid; and the atmosphere would soon become unfit for breathing, were it not for the change of air which takes place through the crevices of doors and windows. Since, then, carbonic acid is of such frequent occurrence, being always present in the air, and being constantly formed at the expense of the oxygen of the latter,—how is it, it may be asked, that the quantity of oxygen does not unduly diminish, and the carbonic acid increase to a most injurious extent?

This question, the solution of which is most important, is intimately connected with another,—namely, whence do plants obtain their carbon? The most simple experiment will prove the presence of carbon in the vegetable kingdom. If we char a piece of wood, a stalk, a leaf, or a piece of dry potato, the carbon becomes manifest, and appears as a black substance like charcoal. This substance is impure carbon. It may, I think, be assumed that carbon, being an elementary substance, cannot be produced by the plants themselves, but must be derived by them from surrounding substances. Now the chemical phenomena of vegetation are accomplished by the concurrence of the elements of the *air*, of *water*, and of the *soil*. A *seed*, with reference to its organization, consists of

an *embryo* (which includes the germs of the root and of the stem), and of the *cotyledon* or *cotyledons*, which form the bulk of the seed. All seeds contain starch and gum, a substance (as in peas and beans) resembling cheese, oily matters, and a certain small portion of ashes; which latter may be seen, if the seed be burnt.

If some seeds be moistened, and placed under a glass containing common air, all the signs of germination will soon be perceived. On examination of the air, after a few days, it will be found to be altered in its composition. It will be seen that a portion of its oxygen has disappeared, and that a corresponding volume of carbonic acid has been produced. Now, we know that seeds will not germinate in an atmosphere deprived of oxygen, and that the process of germination is always accompanied by the formation of carbonic acid. Germination and respiration are therefore akin in this property. Some seeds are known to germinate under water; this is owing to the constant presence in the water of atmospheric air in a state of solution. The larger the quantity of oxygen which immediately surrounds the germinating seed, other things being equal, the greater will be the quantity of carbonic acid generated in a given time. Oxygen is as favourable to germination as the presence of large quantities of carbonic acid is unfavourable; and the process will be manifestly hastened, by placing .

quick-lime near the seed, in order to absorb the carbonic acid as fast as it is formed. The seed at first loses in weight; but, as germination advances, and the roots and stem acquire size and shape, the increase of mass becomes very considerable. A seed of beet-root, of the weight of $\frac{1}{100}$ of a grain, may produce a root weighing twenty-eight pounds. Now, without denying the influence of the soil upon the growth of the plant, it is a well-attested fact, that a seed may give birth to a plant, nay, arrive at perfect maturity, by the mere concurrence of water and air.

Carbon is the predominating principle in dried plants, and is met with in the atmosphere in the form of carbonic acid. Plants, *under the influence of solar light*, are capable of decomposing this carbonic acid; its carbon unites with them, and its oxygen is restored to the air. The researches of Saussure show the necessity of the presence of light in making the carbonic acid act favourably upon vegetation. He found that young plants, under the influence of solar light, decidedly thrive when the atmosphere contained as much as $\frac{1}{11}$ of carbonic acid, and that their growth was evidently more vigorous than when in common air alone; and, at the conclusion of one experiment, he found almost the whole of the carbonic acid replaced by oxygen! He found, further, that the smallest addition of carbonic acid to the air, above its ordinary quantity,

is injurious to plants in the shade. At night time the assimilation of the carbonic acid ceases: oxygen is no longer exhaled from the leaves of the plants; but a true chemical process commences. Oxygen is inhaled by the leaves, and carbonic acid formed at the expense of the carbon contained therein; and this acid is retained, either in part, or wholly, in proportion as the green part of the leaf is more or less plentifully provided with water.

Here, then, we find the solution of the question, how it occurs that the proportion of oxygen in the atmosphere has remained unchanged in the lapse of ages. We find the life of plants connected with that of animated nature in the most simple manner, and for the most wise purposes. The vegetable world not only affords the means of nutrition for the growth and continuance of animal life, but also separates the noxious carbonic acid from the atmosphere, and is an inexhaustible source of pure oxygen, supplying to the air the loss constantly sustained by it in the support of the animal creation. As, therefore, animals *exhale* carbonic acid, whilst plants *inspire* it, the composition of the atmosphere, the medium in which both live, remains unchanged.

Water, also, is ever present in the atmosphere. In the state of *vapour* it exercises a most important influence on the health of human beings and animals, and on the growth of plants. At all temperatures water rises by evaporation into the air, which

therefore, is constantly impregnated with it; it accompanies the air wherever it penetrates, it pervades the pores in the leaves of plants, and gains admission into the lungs and skins of animals. The quantity of vapour which the atmosphere is capable of holding, is dependent upon temperature. When fluid water is present with vapour in large proportions, the latter becomes completely moist and opaque, as in *mist* and in *clouds*. The red and golden tints of clouds appear to be owing to a peculiar property of steam. When steam issues into the atmosphere from under a pressure of from five to thirty pounds on the inch, a light appears, of a deep orange-red colour. The steam possessing this colour is mixed with air, and on the point of condensation. When the temperature of a cloud, containing vapour in large quantities, falls, a portion of the vapour is condensed, and falls in the form of *rain*. When clouds form at temperatures below 32°, the watery vapour is converted into small needle-like crystals, which re-unite with many others, and fall as *snow*. The phenomenon of *hail*, also, is caused by cold, but under different circumstances. Its formation is always attended by electricity, and it seems to be produced in a moist ascending current of air (greatly cooled by rarefaction), having an upward velocity sufficiently strong to sustain the falling hailstones, until they have attained considerable size.

From the preceding remarks, it must be obvious that it is owing solely to the high temperature of the air that the presence in it of water is not always perceptible; for, if a portion of air be cooled, the presence of water is made manifest. If a decanter filled with spring-water, fresh from the well, be brought into a room, the outer surface of the decanter will immediately become covered with *dew*. And so, also, in nature. The appearance of dew always follows a fall in the temperature of the substances on which it is deposited. All bodies on the earth's surface throw out heat in straight lines, every warmer to every cooler body; and thus the tendency of the surface of the earth is always towards a cooler state. When the sun shines, a body receives more rays than it sends out; its temperature, therefore, rises: when a body gives off more rays than it receives, as is the case on a cloudless night, its temperature falls; and thus the cooling of bodies occasioned by nocturnal radiation is always accompanied by a deposit of moisture upon their surface, in the form of minute globules; in fact, by a fall of *dew*.

In very warm climates, the dew is so plentiful as materially to assist vegetation. When the sky is clear and calm, plants cool down during the night, and very soon show a temperature inferior to that which surrounds them. No dew is deposited on cloudy nights, as the rays thrown off by the earth

are returned by the clouds, and the temperature of the air is consequently maintained. Nor does dew fall equally upon all bodies. "Different substances are endowed with the property of radiating their heat, and of thus becoming cool, with different degrees of rapidity; and those substances which in the air become cool first, also attract first and most abundantly the particles of falling dew. Thus, in the cool of a summer evening, the grass-plot is wet, while the gravel-walk is dry; and the thirsty pasture and every green leaf are drinking in the descending moisture, while the naked land and the barren highway are still unconscious of its fall. How beautiful is the contrivance by which water is thus evaporated, or distilled, as it were, into the atmosphere—largely, perhaps, from some particular spots—then diffused equably through the wide and restless air, and afterwards precipitated again in refreshing showers or in long mysterious dews! But how much more beautiful the contrivance by which the dew selects the objects on which it delights to fall; descending first on every living plant, copiously ministering to the wants of each, and expending its superfluity only on the unproductive waste."—*Johnston*.

Nocturnal radiation is frequently destructive to vegetation in spring and autumn, by lowering the temperature several degrees below the freezing point. An unclouded sky affords the principal

condition for nocturnal radiation. Before we had attained to the knowledge that bodies on the surface of the earth, on a clear night, become cooler than the surrounding air, it was difficult to comprehend how the flimsy coverings, which gardeners throw over vegetables for their protection from injury consequent on a low temperature, could be effective. The natives of Peru, having observed that it freezes only when the sky is clear and calm, contrive to create *artificial* clouds, when they are led to apprehend a frost. They set fire to heaps of damp straw, and thus raise a cloud of smoke over their crops—a measure which Boussingault states to be a complete protection.

Water was for ages regarded as an element. Not longer ago than 80 years, it was thought possible to convert it into an earth; and we owe the correction of this error to the great French chemist, Lavoisier. In 1781, Cavendish and Watt first showed the compound character of water.

There is an element called *Hydrogen*, which, when inflamed in contact with air, produces *water*. The latter is a chemical combination of oxygen and hydrogen—so called from two Greek words ὕδωρ (hudor) water, and γένναιεν (gennaein) to generate. Hydrogen is never found in the free state. The compound which contains it in the greatest abundance is water, of which it forms one-ninth. It occurs also in combination with most forms of

vegetable and animal matter ; but the source from which it is always obtained by chemists is from water. When pure, hydrogen is a colourless, tasteless, and inodorous gas. Its specific gravity is 0.693 ; it is therefore $14\frac{1}{2}$ lighter than air, and may be used for inflating balloons. It is very inflammable, but does not support the combustion of other bodies.

If two volumes of hydrogen be mixed with one volume of oxygen, no combination ensues. But, the flame of a burning body, the electric spark, or a red-hot coal, are sufficient to induce rapid combination ; a violent report is heard, and water results. On account of the property of such an admixture of oxygen with hydrogen, to explode on the approach of flame, it is called *detonating gas*, or *explosive gas*.

Hydrogen is like nitrogen in this respect, that it cannot be inhaled in a state of purity. Not that hydrogen is poisonous ; but, inasmuch as oxygen is essential to life, and is prevented from entering the lungs, it becomes injurious.

To water and carbonic acid, whose presence in the air is constant, though small in quantity as compared with oxygen and nitrogen, must yet be added another substance, *Ammonia*, in combination with carbonic acid, as *carbonate of ammonia*. It owes one of its names to the district from which the so-called sal-ammoniac was once obtained—Ammono-

nia, in Africa. It is called hartshorn, because it was first prepared from harts' horns. It is a definite compound of nitrogen with hydrogen. At the ordinary temperature of the air, ammonia is a colourless gas, possessed of a pungent, exciting, and enlivening odour. It is feebly combustible, but does not support the combustion of other bodies. Animals die when immersed in it. Red vegetable colours are turned blue by it. The gas is very soluble in water; one measure of the latter will absorb as much as 700 measures of the former. The thus-formed liquid ammonia of the shops is possessed of all the pungent properties of the gas. Nor does it lose these properties when combined with carbonic acid, for carbonate of ammonia still emits a pungent odour. In the atmosphere, however, it is contained in such minute quantities, that it is never known to communicate even the faintest odour to it. According to Fresenius, one million parts of air contain only 0.283 parts of carbonate of ammonia by day, and about twice that quantity by night. The comparative smallness of the quantity present by day is probably owing to two causes: 1, that in the daytime more ammonia is expended in the nutriment of plants; 2, that the ammonia which accumulates during the day and night together, is dissolved and precipitated by the dew at sunrise. Be this as it may, it is certain that the ammonia of the air does supply wild plants with

much of the nitrogen required for their growth. It is well known that in the process of decay and putrefaction, ammonia is constantly evolved from all vegetable and animal matters containing nitrogen. We know, also, that salts of ammonia are products of the combustion of both wood and coal. From many sources, and at all times, ammonia rises into the air, and plays an important part in vegetable nutrition. It is certain, not only that salts of ammonia have been discovered in the juices of many plants, but that the roots are capable of taking them up. And it is equally certain that guano, and such-like manures, owe much of their value to the large amount of ammoniacal salts which they contain.

I have now mentioned all the constituents of the atmosphere; but it is capable, nevertheless, of being impregnated with many other matters. Thus, near the sea, the air is always found to contain *common salt*, and, indeed, all the other constituents of seawater. In large cities, it is more or less contaminated by the various gases evolved in the different processes of decay and putrefaction, and by the chemical operations carried on in such places.

But, setting aside these trifling differences, we may well ask how it is that the air should maintain its composition so constantly? All experimentalists agree in this, that specimens of air brought from districts the most remote—from London and from New York, from Mont Blanc and from Chimborazo—

preserve an absolute identity of composition. The principal difference is in the quantity of watery vapour ; this, however, it would be natural to expect. But, when we consider that the atmosphere is a mere *mixture* of gases, that no *affinity* whatever exists between its various constituents, that all bodies which possess attraction or affinity for oxygen combine as easily with it as if nitrogen were not present, that every passing rain removes those gases which are the most soluble ; further, when we remember the still more remarkable fact, that all the gases contained in the air are of different specific gravity, that there is as great a difference between the weights of oil and water as exists between those of nitrogen and carbonic acid, we are lost in amazement, and ask, How can such things be ?

Now these difficulties may be explained upon the principle of what is called the *law of the diffusion of gases*. This law (known as Graham's law) is found to be entirely independent either of specific gravity or affinity, and may be thus briefly stated: the particles of one gas, though highly repulsive to each other, do not repel those of a different kind ; hence one gas acts as a vacuum with respect to another. Were it not for this law, the carbonic acid evolved in such vast quantities in our large towns would collect, and would speedily destroy their inhabitants. The foul and noxious gases which constantly arise

from the numerous operations of a large city, would spread disease and pestilence around it. Were it not for this law, the perfume of flowers, and the sweet scent of newly-mown hay, would not arise to fill our hearts with a sense of gladness; but would fall from their own weights on the senseless earth. Were it not for this law, the oxygen would separate from the nitrogen, and a universal conflagration, which no water could subdue, would arise on the ignition of the first fire. In fact, were it not for this law, there could be no life. Vegetation must languish and die, for want of a supply of carbonic acid, which, by this provision, is wonderfully and completely diffused throughout all the particles of air. The watery vapour, of no less importance, would not, as now, keep flexible the skin of animals, and supply parched vegetation with rains and dew. In the process of respiration, the minute cells of the lungs, in which the real aëration of the blood takes place, would not, as now, be emptied at each exhalation of the heavy carbonic acid which they contain; but the process would, after a few minutes, be suspended, and death would ensue.

It is, indeed, a most necessary and beneficent law, and is well calculated to fill our minds with awe at the power, and gratitude for the goodness of that God, who, in the words of the patriarch, "bindeth up the waters in His thick clouds, and the clouds are not rent under them."

I have thus noticed the composition and the most important properties of the air we breathe; and prepared the way for the subject with which I intend to follow up this chapter.

QUESTIONS ON CHAPTER I.

What are the physical (natural, from φύσις, phusis, nature) properties of the air? To what extent is it limited? Why do we not ordinarily feel the pressure of the air? How is its temperature determined? Describe a thermometer. What is the meaning of the word? How many kinds are there? In what does the difference consist? What is the ordinary temperature of the air?

How may the weight of the air be measured? By what instrument? What is the meaning of the word barometer? Why is quicksilver used in preference to water? How does the barometer indicate weather?

What are the names of the two constituents of the air? Is oxygen of frequent occurrence? What is the meaning of oxidation? What is the word derived from? What are the several uses of oxygen?

What of nitrogen? What other name does it go by, and why is it so named? What can be the object of so large an admixture of this gas?

What do you know of carbonic acid as regards its presence in air? Is there more of it on the mountains than on the lowlands? Does the quantity of it vary in the twenty-four hours of the day? What are its sources? Can you give an idea of the quantity given out to the air in one place? What is it composed of chemically? Does carbon bear any other names? Is there any reason for these? What are the properties of carbonic acid gas under ordinary circumstances? Is it poisonous? To what extent is it soluble in water? What is

the meaning of effervescing? What is the gas which usually causes effervescence?

How is it that carbonic acid, from its weight, does not unduly accumulate? How can you prove carbon to be present in plants? What are the three means which accomplish vegetation? What are the phenomena of vegetation? In what respects are germination and respiration alike? Is oxygen favourable to germination? Whence do plants obtain their carbon?

In what state does water exercise much influence upon plants? Is the quantity of water at all times equal in the air? Why does it sometimes fall as rain, and at other times as snow or hail? Why cannot the water in the air always be seen? What occasions the fall of dew? Does it fall equally on all bodies? Why does nocturnal radiation injure vegetation? How do market gardeners prevent it? Who discovered the chemical composition of water? What is the word hydrogen derived from? What are its properties? How can water be formed artificially? What is detonating gas? Why is it so called? Is hydrogen poisonous?

Is hydrogen a constituent of any other compound besides water? What is ammonia? Why is it so called? What is hartshorn? Why should we have some knowledge of this substance? If contained in the air, why do we not smell it? Why does the night-air contain most carbonate of ammonia? What is the reason of its presence in air? Is ammonia ever found in vegetables? Is it in manures?

Are there ever other accidental constituents of air, besides oxygen, nitrogen, carbonic acid, water, and carbonate of ammonia?

How is it that the air so evenly maintains its composition? By what law is it explained? Recite the law? What are the effects of the law? Is it necessary?

CHAPTER II.

THE CHEMISTRY OF COMBUSTION, AND OF THE ARTIFICIAL SOURCES OF LIGHT AND HEAT.

I HAVE already alluded to the fact, that the oxygen of the air plays the part of supporter of combustion. Combustion is always accompanied by the phenomenon of heat, and frequently by that of light. In fact, the two are disposed to produce, and are probably convertible into, each other. The rays of the moon form, it is true, a supposed exception to this rule; but it will cease to be matter of wonder, that our best instruments do not indicate any heat in them, when we reflect that a single ray of the moonbeam possesses only the 1-300,000th part of the light of a solar ray of the same size !

In all ordinary cases of combustion, *air* is present, and all the phenomena of combustion may be explained by the sudden chemical action which ensues at high temperatures between the burning

body and the oxygen of the air. Not that any temperature can be fixed at which bodies burn or inflame in air ; on the contrary, some take fire the moment they are exposed to it ; others at a temperature a very little above that of summer-heat ; some at a very high temperature ; others again refuse to burn under any condition. The products of combustion, the result of the union between the oxygen and the burning body, are usually gaseous, and hence they escape the notice of the ordinary observer. Before, however, we can, with any profit, consider these products, we must well understand the nature of those bodies which are more or less employed as sources of light and heat.

I have already called attention, in some degree, to that fundamental constituent of all sources of flame, *Carbon*. It is of universal occurrence in the animal and vegetable kingdoms, and is found largely in the mineral kingdom ; it forms the chief constituent of *coal* ; and combined chemically with oxygen, as *carbonic acid*, it is met with in the air, and in water, in limestone and marble combined with lime as carbonate of lime, and in not a few minerals besides. A lump of carbon or charcoal undergoes no change on exposure to air, or when buried in the ground ; its affinity for oxygen is not exhibited at ordinary temperatures. But heat it to redness, combustion takes place, the charcoal burns and disappears, with the exception only of a small quantity of *ash*. The

heat developed is the result of its union with the oxygen of the air. The gas generated from the lump of charcoal, or, in other words, the gas into which the charcoal is converted, is called *carbonic acid*, which forms with lime-water (as has been already stated), a white precipitate of carbonate of lime.

Carbonic acid, then, is a chemical combination of carbon with oxygen. By whatever method it may be prepared, it has always the same composition, for it is a law of nature that chemical combinations always take place according to certain fixed proportions, by measure and by weight. This law is the very basis of chemistry, without which the science could have no existence. The *relative* quantities, too, in which bodies unite, may be expressed by proportional numbers. Thus : 16 parts of oxygen unite with 6 of carbon, to form 22 parts of carbonic acid.

Not that carbonic acid is always the result of the union of carbon with oxygen. When coal burns at a temperature below redness, or when carbonic acid passes over hot coal, the carbon unites with less oxygen in the first case, and with more carbon in the second. The result is, the formation of a new compound, *carbonic oxide*. It is a colourless gas, of a faint, peculiar odour, and even more poisonous than carbonic acid. It is inflammable. The blue flame often to be observed in coal fires, arises from

the burning carbonic oxide, which unites with more oxygen, and becomes changed into carbonic acid.

We are now acquainted with two combinations of carbon with oxygen. Employing the language of chemists, in expressing the elements by the first letter of their Latin names, the *combining proportions* of these two compounds are as follow :—

$$\text{Carbonic oxide} \quad \left. \begin{array}{l} \text{C} \dots 6 \\ \text{O} \dots 8 \end{array} \right\} = 14$$

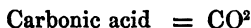
$$\text{Carbonic acid} \quad \left. \begin{array}{l} \text{C} \dots 6 \\ \text{O} \dots 16 \end{array} \right\} = 22$$

The *equivalent* (so called, because the combining proportion of one body is, as it were, equivalent to that of another body, and may be substituted for it in combination,) of carbonic oxide is, therefore, expressed by the figure 14; that of carbonic acid by 22. One hundred parts of these compounds consist of :—

$$\text{Carbonic oxide} \quad \left. \begin{array}{l} \text{C} \dots 42.86 \\ \text{O} \dots 57.14 \end{array} \right\} = 100.00$$

$$\text{Carbonic acid} \quad \left. \begin{array}{l} \text{C} \dots 27.27 \\ \text{O} \dots 72.73 \end{array} \right\} = 100.00$$

And not only are the elements expressed in symbolic language, but also the proportions in which they are united in chemical compounds. Thus, in the case of carbonic acid, the equivalent of oxygen is 8. To express the two equivalents of oxygen by a symbol, we write :—



But to continue our subject. Next in importance to Carbon, as a source of heat, is *Hydrogen*. Its symbol is H. It is the lightest form of matter we are acquainted with, an equal volume of common air being fourteen and a half times its weight. Although it is not a supporter of combustion, and is, in the absence of air, an extinguisher of flame, yet, when inflamed in presence of air, it burns with a pale blueish hue, and emits very great heat. The product of the union of hydrogen with oxygen, is pure *water*, which is as much a definite compound as any with which we are acquainted. And in mentioning the composition of water, I will say a few words upon the *atomic theory*. What I have written upon the subject of the laws of chemical combination, is founded upon experiment; but of the exact nature of the ultimate elements of matter we can only form an idea, although the atomic theory offers the only satisfactory explanation of these laws. It is believed that matter is composed of certain ultimate particles or molecules (diminutive from *moles*, a mass), which by their nature are indivisible, and are hence called *atoms*, from α (a), not, and $\tau\epsilon\mu\nu\epsilon\iota\nu$ (*temnein*), to cut. According to this theory, every compound is formed of the atoms of its constituents. Thus, water is composed of 8 parts of oxygen and 1 of hydrogen. The combining proportion of oxygen is therefore 8, that of hydrogen 1. Instead of describing water as a compound of 1 eq.

(short for equivalent) of oxygen, and 1 eq. of hydrogen, it is said to consist of 1 *atom* of each element, in which case the atom of oxygen is eight times the weight of an atom of hydrogen. Again, if carbonic oxide be formed of 1 atom of carbon and 1 of oxygen, the relative weights of their atoms are as 6 to 8; and so the equivalents of all bodies express the relative weights of their atoms.

Exact experiments have shown that two measures of hydrogen unite with one of oxygen. In forming water, the three measures condense into two measures. An admixture of these two gases in the proportions to form water, is productive of the greatest amount of heat. The *oxy-hydrogen* flame is capable of fusing the most intractable metals, platinum being softened and melted by it as easily as gold in a furnace.

The *flame* of such a light is weak; indeed it is believed that pure gaseous matter is not capable of giving out *light*. Certain it is, that the heat of a flame is independent of its light, and that the flame will prove to be the hottest in which hydrogen most abounds. It is well known that common air may be heated to such an extent, that it will inflame pieces of wood, and yet itself remain invisible. A good instance of this is afforded by the air which issues from the chimney-glass of an argand gas-burner, which will make a thin piece of wire red-hot, even when held several inches above the flame.

To carbon and hydrogen, as sources of light and heat, must be added *oxygen*. It may be produced artificially from a variety of sources; but the principal feature to which I have to call attention, is the extraordinary brilliancy with which bodies burn in it. Bodies which burn in the air burn with greatly increased splendour in oxygen. If a taper be blown out, and then introduced while the wick remains red-hot, it is instantly rekindled: a slip of wood, or a match, is relighted in the same manner. When a piece of charcoal is affixed to a wire and plunged with a single point red-hot into a jar of oxygen, it burns with great brilliancy, throwing off beautiful scintillations, until, if the oxygen be in excess, it is completely consumed. Coiled watch-spring, heated to redness, and immersed into a jar filled with oxygen, exhibits a most beautiful appearance of combustion. Phosphorus, when inflamed in the air, where the oxygen is mixed with four times its volume of nitrogen, burns with a very bright light; but it is no more to be compared with the brilliancy of phosphorus, inflamed in oxygen, than is the light of the sun to that of the moon. In these, and in other cases which might be mentioned, the same ultimate effect is produced, as in atmospheric air. It is, in fact, the *sustaining principle of combustion*. The compounds formed by the direct union of oxygen with other bodies, bear the general name of oxides and acids. It sometimes happens that an

element unites with oxygen in several proportions, forming a series of oxides to which it is necessary to give distinguishing names. When two oxides occur, it is usual to call the highest oxide *peroxide*, (from the Latin prefix signifying excess), the lowest, or that which contains least oxygen, *protoxide*, (from *πρωτος*, *protos*, first). A compound containing less oxygen than the protoxide, is called a *sub-oxide*, (from *sub* under or beneath). The abstraction, separation, or removal of oxygen, is called *reduction*, or *deoxydation*. All the elements are capable of oxydation, and most of them at a temperature more or less high, with the evolution of heat and light. A substance incapable of further entrance into combination, such as water and carbonic acid, is called *incombustible* or *uninflamable*. All organic bodies are *combustible*. Whenever a body unites with oxygen, it increases in weight by as much as it has absorbed of the gas. The term *destruction* of bodies by combustion, is therefore incorrect, inasmuch as matter is *indestructible*; in fact, when we *seem* to destroy a candle, or a lump of coal, by burning them, we only compel them to enter into new forms of combination, which being gaseous, are either immediately dissipated in air, or may be detected escaping up the chimney. When the product of combustion happens to be a *solid* body, as in the case of inflamed phosphorus and zinc, we can more readily believe the evidence of our senses, as we may handle and

weigh the phosphoric acid and oxide of zinc thus produced.

In COAL, we see the remains of a vegetation which covered the earth before it was inhabited by man. It has probably arisen from plants and trees of an early period, which have been buried, by the violent agencies of water and other causes, under mighty strata of sand and clay. Here it has become slowly and partially decomposed, whilst the beds of sand and of clay have been hardened by time into sandstone and slate. The pressure of these deep strata has not only prevented the evolution of gas, thus giving to the coal the property of burning with flame, but has, to a great extent, obliterated all appearance of vegetable structure, and given the substance the close and compact quality of stone.

The difference in the appearance of the several varieties of coal is not greater than the difference in their composition. The principal constituents of coal are carbon, hydrogen, oxygen, and nitrogen. Of these, carbon, hydrogen, and oxygen, may be considered as the elements of *pure* coal; but it always contains a great number of earthy impurities, or *ash*. The different kinds of coal comport themselves in the fire as ordinary organic substances, in which the combustible elements, carbon and hydrogen, are condensed into a small volume. For gas illumination the value of the coal is propor-

tional to the quantity of volatile matters which it disengages at a red heat. Thus, Mr. Mushet found in—

	VOLATILE MATTER.	COKE.	
		Carbon.	Ash.
Derbyshire coal . . .	47·000	48·362	4·638
Scotch cannel coal . .	56·570	39·430	4·000
Welsh furnace coal . .	8·500	88·068	3·432

The composition of *pure* splint and cannel coal, according to Richardson and Regnault, is represented by the formula $C^{24} H^{13} O$; which gives, when explained in proportions per cent.:—

Carbon	87·27
Hydrogen	7·88
Oxygen	4·85
	<hr/>
	100·00

Nitrogen does not seem to be an element of pure coal; but as all kinds of coal give, on distillation, a larger or smaller proportion of products containing ammonia, we must suppose its existence to be constant. We do not know in what form the nitrogen exists; though given off in combination with hydrogen as ammonia when coals are burnt, it certainly does not pre-exist in the latter form.

The *ash* of most kinds of coal consists of *clay*, *gypsum*, *chalk*, and *carbonate of iron*. Unfortunately for some applications of coal, especially that of making gas, few varieties are free from *iron*-

pyrites. This mineral is generally visible to the naked eye, presenting frequently a gold-like appearance. It contains sulphur, or brimstone. The presence of that most nauseous gas, sulphuretted hydrogen, in unpurified coal-gas, is derived entirely from the iron-pyrites.

Of the many numerous services which Chemistry has rendered household economy, there is certainly none which possesses more general importance and interest, and none that has been more fully developed, than that of lighting by means of gas obtained by the destructive distillation of coal. Although its application as a means of procuring artificial light is of modern invention, yet the germ of it may be traced back nearly two hundred years. Dr. Robert Clayton, Bishop of Cork and Ossory, first distilled coals in a retort and obtained gas. He says: "I kept this spirit (gas) in the bladders; and, when I had a mind to divert strangers or friends, I have frequently taken one of these bladders and pricked a hole therein with a pin, and compressing gently the bladder near the flame of a candle till it once took fire, it would then continue flaming till all the spirit was compressed out of the bladder; which was the more surprising, because no one could discern any difference in appearance between these bladders and those which are filled with common air." But the first application of coal-gas in illumination was made in 1792, by Mr. Murdoch.

Novel as was this mode of lighting his own dwelling, it did not attract public attention until the year 1802, when the front of the Soho manufactory of Messrs. Bolton and Watt was lighted by him with a public display of gas-lights, on occasion of the national illumination in the spring of that year at the peace of Amiens. In 1810, the National Light and Heat Company obtained an act for the purpose of illuminating London streets, and before 1825 every oil-lamp in the public streets was displaced by gas. How much more general the application of the process has since become, need not be mentioned.

The production of *coal-gas*, or *street-gas*, is a trade of great magnitude and importance. The coal is placed in oblong cylinders of cast-iron, which are ranged in furnaces, to keep them at a red-heat, and all the volatile products are conveyed by a tube in connexion with all the cylinders into a condensing vessel, kept cold by immersion in water: here all the condensible vapour, such as water, tar, ammonia, and other impurities, are retained. The coal-gas, still more or less impure from the presence of carbonic acid and sulphuretted hydrogen (a gas also evolved from rotten eggs), is now passed through a mixture of slaked lime in water, in vessels called purifiers. The lime frees the gas of its impurities, with which it combines chemically, but it has no affinity for the gas itself. The latter is sometimes still further purified by passing through

diluted sulphuric acid, or a solution of sulphate of iron, which removes all traces of ammoniacal gas and sulphuretted hydrogen; it is then transmitted for use into gasometers, whence issue the pipes for the supply of streets, shops, and private houses.

The largest quantity of gas obtainable is from the Scotch cannel coal, a ton of which affords nearly 12,000 cubic feet. The various kinds of coal employed throughout the kingdom yield, on an average, 8000 cubic feet.

The substances to which the illuminating power of coal-gas is due, are mixtures of distinct chemical compounds of hydrogen and carbon. They are called *hydro-carbons*.

The chief constituent of coal-gas, as regards quantity, is *light carburetted hydrogen*. It consists, in 100 parts by weight, of 75 of carbon and 25 of hydrogen; proportions which correspond to one atom or equivalent of carbon and two of hydrogen. Its symbol is, therefore, CH^2 . It is a colourless, tasteless, and nearly inodorous gas. If a burning taper is introduced into a jar of this gas, it is extinguished; but the gas itself burns with a *pale yellow flame*, when kindled in the air. The mixture of air or oxygen with this gas, explodes violently by contact with flame. For complete combustion it requires twice its bulk of oxygen, and affords water and its own volume of carbonic acid. Light carburetted hydrogen is the main constituent

of *Will-o'-the-Wisp*. (The latter is probably kindled by the presence, in minute quantities, of spontaneously inflammable phosphuretted hydrogen—a gas the product of the putrefaction of certain parts of vegetables and animals). Indeed, it may be readily procured by inverting a bottle, into the neck of which a funnel has been fixed by means of a perforated cork, filled with water in a stagnant pool, stirring the bottom of the pool with a stick, and catching the bubbles which rise in the funnel; the water is displaced, and the bottle filled with the gas.

Although, as regards quantity, light carburetted hydrogen forms the bulk of street gas, yet must *olefiant gas*, or *heavy carburetted hydrogen*, be considered its most important constituent. It obtained its one name from its property of forming an *oil-like* compound with chlorine; its other, on account of its weight, as compared with light carburetted hydrogen. The specific gravity of the two gases, compared with air, is as follows:—

Air	. . . . .	1000
Olefiant gas	. . . . .	996·87
Light carburetted hydrogen		560·45

It is a colourless and tasteless gas, of ethereal odour. It consists, by weight, of 85·71 of carbon, and 14·29 of hydrogen; or, by volume, of two volumes of carbon vapour and two volumes of hydrogen *condensed into one volume*. Its symbol is

$C^4 H^4$. The peculiar luminosity of its flame is accounted for by its extraordinary condensation. In contact with air it burns with a remarkably white flame, producing water and carbonic acid.

Besides these two hydro-carbons, there are others present in minute quantities, which communicate to coal-gas its peculiar odour. Carbonic oxide and nitrogen are also present. One hundred volumes of coal-gas contain about thirteen volumes of olefiant, and eighty-two volumes of light carburetted hydrogen gas.

The whiteness of the flame of coal-gas is then due to olefiant gas; accordingly as this increases or decreases, is the beauty or pallor of the flame. What is it, it may be asked, which renders olefiant gas so valuable as a source of light? I have already mentioned that pure gaseous matter is incapable of giving out light. No flame possesses so little light as that of oxy-hydrogen, none such intense heat. The luminosity of flame does not depend so much on its temperature, as on the presence of solid matter diffused through the flame and ignited by it. *A luminous flame always contains solid matter heated to whiteness.* It is true these cannot always be seen, but they are nevertheless present. Let us examine into the case before us. When coal-gas burns, no solid matter can be seen in its flame; but if you depress a white saucer into the flame, you find it immediately covered with *solid* carbon, or

soot, and the light impaired. *This carbon in a state of white heat is the cause of the luminosity of all ordinary flames.* In an ordinary gas-flame, the gas is in free contact with the air only in the blue part at the bottom, and on the very outside of the flame. Perfect combustion, therefore, only takes place at those parts. In the interior or brilliant part of the flame, the air supplied is insufficient, and the heat so great, as to separate the coal-gas into its constituents, hydrogen and carbon. The hydrogen burns (forming water), while the carbon is deposited in a state of white heat, and is only converted into carbonic acid on the exterior of the flame. That flame requires a high temperature for its existence, is proved by the fact that any cold substance depressed upon it removes a portion of its carbon. The great condition that must be complied with in order to obtain a bright light from *gas*, is to take care that it has a constant supply of fresh air. Its hydrogen and carbon must be burnt completely: when the combustion of carbon is incomplete, not only does the flame smoke, but much light is lost. This is accomplished by two methods. By the first, the gas is made to stream out in thin apertures, surrounded both internally and externally by air, as we see in the common Argand burner; by the second, not only is the gas protected externally by the chimney-glass from any sudden gusts of cold air, but the brightness of the flame is greatly increased

by a continued stream of air which rushes in regularly from below the glass, exactly in the proportion as the heated air streams out from above. In proportion as the draught is increased, will the flame be brighter.

The increase of light is, of course, far greater, in the case of an Argand burner, if, in the place of air, oxygen is passed up the internal opening. The *Bude light* of Mr. Gurney was originally so constructed. But the light now known as such, is nothing more than an ordinary gas-flame from three or more large concentric Argand burners, with chimneys and reflecting apparatus.

To obtain a full amount of light from any burner, the flame should always be made as large as possible without smoking.

Of the economy of gas, as compared with all other sources of light, no doubt exists. But wherever it is used, more than ordinary attention should be paid to ventilation. When we consider that one part by weight of coal-gas produces two and a half by weight of poisonous carbonic acid, the importance of this observation will be readily admitted. Head-aches are the least penalty paid for the neglect of this precaution.

Whilst yet on the subject of coal-gas, I must mention another property of flame. The inflammable gas which escapes from fissures in coals, the so-called *fire-damp* of miners, has almost the same

composition as coal-gas. When it accumulates so as to form 1-7th of the atmosphere in a coal-mine, the approach of flame instantly causes a tremendous explosion, and the poor miner is either burned to death, or choked by the carbonic acid or choke-damp formed in its combustion. To remedy this, Sir H. Davy undertook many experiments, which at last led to the construction of that most ingenious instrument, the miner's *safety-lamp*. Its efficacy depends upon the fact, that flame requires a high temperature for its existence; and that such an explosive mixture is not inflamed at a temperature below red-heat. If you take a piece of wire-gauze, of such fineness as to have about 800 apertures to the square inch, and depress this quickly upon the burning gas-jet, you will find that the flame will be cut off just where it touches the gauze. The inflammable matter of the flame (much of the undecomposed gas, together with a good deal of soot) passes through the gauze. In its passage it is so far cooled as to be extinguished; the *flame*, therefore, is prevented from passing, although the gas is not. If you bring a piece of lighted paper above the flame, to the upper side of the gauze, the gas will be rekindled, and burn as before. Again, by varying the experiment, and turning on an unlighted jet of gas underneath the gauze, you may kindle the flame above, and it will not pass. The cooling property of the wire-gauze is owing to its great power

of conducting heat. Sir H. Davy, who is the author of these and many other experiments on flame, placed a lighted lamp within a perfect cylinder of wire-gauze, and found that although inflammable gases would pass through and could be enkindled, yet the flame would not be communicated to the air without; hence its value in mines, where combustible gases are of frequent occurrence. The safety of these lamps depends of course entirely upon the perfect state of the wire-gauze.

Combustible as most kinds of coal are, they must be heated to a certain extent before they will inflame. This is accomplished by the use of the more readily combustible paper and wood. They are laid in the grate, and the coal is heaped upon them in such a manner, that the air may have free access. When the coal is heated below redness, its hydrogen unites partly with its own oxygen, partly with that of the air, and escapes up the chimney in the form of steam. The heat at first is usually insufficient, and therefore a quantity of the carbon of the coal is separated from the hydrogen, with which, and with the oxygen, at a higher temperature it would otherwise have been combined, and passes likewise up the chimney. At length, after the heat has been somewhat increased, the olefiant and other gases burst out into flame, which continues as long as the supply of the hydrogen lasts. As long as there is any carbon, the coals retain their glow,

and continue to burn, though no longer with flame, until nothing remains in the grate but the incombustible ashes, which consist mainly of silex, gypsum, and clay.

And now, with reference to the actual combustion of the fuel ; we know that this is due to its union with oxygen. In the combustion of coal, carbonic acid, and watery vapour, are mainly formed ; together with small quantities of sulphurous acid and ammonia. Of the properties of carbonic acid, of its power of extinguishing flame, and its heavy character, I have already spoken. Its weight, indeed, would very seriously interfere with the burning of the coal, were it not for the important fact that the heat evolved by the combustion itself, is the very agent by which it is carried off as fast as it is produced. When this, or any other gas, is heated, its particles expand ; its actual weight remains unchanged, but it occupies a larger space. When a portion of air is heated in the open atmosphere, it expands and rises upwards, not because it has, of itself, any tendency to rise, but because the heavier cold air around displaces it, and makes it ascend. A flame ascends simply because the heat given out by it expands the surrounding air, and makes it lighter than air usually is. The heat evolved not only ensures the removal of the carbonic acid, but also causes a circulation of fresh air through the burning fuel. In a good grate, therefore, all these gases are carried

off up the chimney, upon the *draught* of which the burning of the fire greatly depends. A fire, therefore, serves the purposes both of ventilation and heat. When the weather is cold, we make a large fire, and thus, of course, expand a larger volume of air than usual, in consequence of which a larger amount of cold air will rush into the room. The ascent of smoke then being dependent upon the admission of colder air, the fire will only burn well, and the chimney draw, in proportion as we allow it to enter.

The waste of fuel, which takes place when much of it is allowed to escape in the form of smoke, arises solely from insufficient access of air, and might be, if not entirely, at least in great part, prevented.

As to the temperature of a fire, I may mention that a dull red heat, visible in daylight, is probably equal to $1,000^{\circ}$, a full red-heat to $1,200^{\circ}$, an orange-heat to $1,700^{\circ}$, and a white heat to $3,000^{\circ}$. The latter is rarely, if ever, attainable in a common fireplace.

PEAT and TURF consist mainly of the remains of plants which have undergone comparatively little change.

WOOD may be said to consist of nearly equal weights of carbon and the elements of water. From this it may be inferred, that wood fires will not only burn with much flame and little smoke, but will give out intense heat, and waste very fast. There is also

a very peculiar odour which usually accompanies the burning of wood. Among the products of the destructive distillation of wood (which are very different from those of coal), are *wood-naphtha*, *vinegar*, and *creosote*, and it may, therefore, be expected that the vapours of the burning wood will, according to the temperature of the fire, more or less partake of the odour of these.

COMMON CHARCOAL, employed as fuel, is usually made of oak, chestnut, elm, beech, or ashwood. Young wood fortunately affords better charcoal than the finest timber. The billets are formed into a conical pile, which, being covered with earth or clay, is suffered to burn with a limited access of air. The oxygen and the hydrogen of the wood combine to form water, and but little of the carbon is consumed. Wood charcoal contains about two per cent. of salts, which, after combustion, remain in the form of ash; but the quantity and quality vary according to the nature of the timber.

Having thus far drawn attention to FUEL, and one of the products of its destructive distillation, I shall now again direct it to the subject of flame. In the chemistry of a CANDLE, we must first consider the various materials of which candles are formed.

The best candles are made of WAX, a substance either collected by bees from the pollen and other parts of flowers, or produced by those insects from sugar. When fresh from the honeycomb, it is of a

yellow color, and possesses a peculiar smell. Exposed in thin layers to the action of sunlight, it loses both smell and color. By the action of hot alcohol, wax may be separated into two distinct substances, *cerine* and *myricine*. They are compounds of carbon, oxygen, and hydrogen, but their exact composition is as yet unknown.

SPERMACETI is found in certain hollows in the head of the various species of delphinus. During the life of the fish it is dissolved in spermaceti oil, but at death it separates in hard crystalline masses. Freed entirely from the oil, it may be said to consist of *cetine*, a crystalline substance of pearly lustre. It is a neutral fat, composed of carbon, hydrogen, and oxygen. Atomically, it is composed of $C^{64} H^{66} O^4$.

TALLOW is the fat of oxen and sheep melted and freed from its natural impurities. The inferior tallows have a yellow tinge; but when pure they are white and tasteless. The best tallow is used for candles; inferior for soap. About 70,000 tons are annually imported from Russia and Australia, besides the quantity supplied from slaughter-houses.

The chief ingredient in tallow is *stearine*, or *stearate of glycerine*. Stearine, so named from *stear* (stear), tallow, is quite insoluble in water, but soluble in hot alcohol and ether. It is much employed, when mixed with a little wax, in making *composite*, or *stearine* candles. When properly made, they are white and inodorous, and burn with as white a

flame, though a little more rapidly than wax. The name stearate of glycerine gives a better insight into the character of the chief constituent of tallow than does stearine. It is a compound of *stearic acid*, the subject described, with *glycerine*. Stearic acid is represented by the formula $C^{68} H^{66} O^6$. Glycerine differs materially from it. It is a syrupy liquid, rather heavier than water, in which it may be dissolved to any extent. It has a sickly sweet taste, which gave occasion to the name, from *γλυκύς* (glukus), sweet. It burns with a bright flame. It is composed of $C^6 H^8 O^6$.

Margarine, or *margarate of glycerine*, is also to some extent a constituent of tallow. It is solid at common temperatures, but less hard than stearine. The only acid peculiar to margarine, *margaric acid* (from *μαργαρίτης*, margaritees, a pearl, on account of its pearly lustre), greatly resembles stearic acid. Its formula is $C^{68} H^{66} O^6$. Margarine is the chief constituent of human fat and goose fat, and is contained in most fats and oils.

Oleine, or *oleate of glycerine*, we also find in tallow, but to a very small extent as compared with the liquid fats or oils. *Oleic acid* is an oily liquid, of a slightly yellowish tint. It reddens blue litmus paper, has a weak odour and pungent taste. It is soluble in alcohol and ether. Its formula is $C^{44} H^{39} O^4$.

CocOA-OIL, extracted from the kernel of the com-

mon cocoa-nut, is white. It contains oleine and a solid hard fat, often used as a substitute for tallow in making candles.

It is obvious, from what has already been stated, that the consistence of oils and fats must be related to the proportion, in the oil or fat, of oleine on the one hand, and of stearine and margarine on the other. Where stearine predominates, the fat is very firm. If margarine abounds, it is soft like lard; if oleine, it is liquid.

I do not think it necessary to enter into the mechanical process of making candles from wax, stearine, tallow, cocoa-nut oil, or spermaceti, as no part of it requires explanation.

All the materials enumerated above inflame of themselves at a high temperature, and burn with a very bright flame. But the temperature which renders them gaseous, decomposes them, and they emit a suffocating odor. It must therefore be evident that they could not subserve the purpose of lighting a room, unless by some contrivance the melted materials should undergo complete combustion. Fortunately they all *melt* at a comparatively low temperature, and act as liquids. By the use of *wicks* we are enabled to effect the two desiderata. These are usually made of twisted cotton, the separate threads of which act as narrow tubes, and draw up the oil or melted tallow by what is called *capillary attraction*. In composition, these wicks partake much

of the character of dry wood: for complete combustion they require a larger amount of oxygen than they ordinarily obtain, and therefore need *snuffing*, because the whole of the carbon cannot be consumed. In order to supersede the necessity for snuffers, wicks are now prepared, in which either a thin metallic wire is interwoven, or which are steeped in solutions of nitrate of bismuth or lead, salts containing large quantities of oxygen, which, at the high temperature of the ignited wick, oxidizes and consumes it. Wicks are sometimes made of asbestos, a mineral substance upon which fire possesses no action: even thin glass tubes are used, in oil-lamps, to supply their place.

Before considering the flame of a candle, it will be as well to clear the way of every difficulty. All the sources of light which we have so lately enumerated consist only of carbon, hydrogen, and oxygen, in certain fixed proportions. The affinity of the hydrogen for the oxygen is greater than that of the carbon. The gases which are obtained from the tallow or wax, in passing through the inflamed wick, are very similar to coal-gas. They are mixtures of olefiant gas with light carburetted hydrogen, and in speaking of them I shall simply call them *gas*.

The light of the flames of tallow, wax, and oil, is due to the same cause as that of coal-gas. The process is as follows: the melted tallow or wax is drawn by capillary attraction into the burning wick; there

it is decomposed and converted into gas, which rises in a conical form, and is of a temperature sufficiently high to unite with the oxygen of the air. But this combustion is superficial only, as the flame includes a portion of heated vapour which cannot burn for want of oxygen. If the structure of the flame be examined yet a little more minutely, it is seen to consist of three distinct parts. The *dark* centre represents the unburnt combustible cone of gas. The *brilliant* part of the flame, or that which gives out light, surrounds the dark cone; in this the gas is decomposed, the hydrogen alone burns, while the carbon is deposited in minute particles, which become heated to whiteness. And then, again, on the very *exterior* is another portion, scarcely visible, in which the carbon burns. The combustion of the hydrogen produces the heat of the candle, and the particles of carbon radiate the light. The heat in the centre of the flame is so low, that gunpowder may be held there without becoming ignited. The hottest part of the flame is just at the top of the luminous cone, where the combustion is perfect.

The chemical effects produced on many substances by the exterior and interior parts of the flame, are exactly opposite. Just within the luminous cone, most compounds of oxygen are *deprived* of their oxygen, or *de-oxydized*; but at the summit of the flame, metals are *oxydized*. If a piece of copper wire is held at the very apex of the flame, it

rapidly becomes covered with a coating of oxide of copper; but, on depressing the wire into the interior of the flame, the oxide is *reduced* (as it is called, from *reducere*, to lead back again), and the wire again becomes bright.

When the combustion of a tallow or wax candle is complete, nothing but carbonic acid and water is given out to the air. *There is no smell.* But if a lighted candle or lamp be carried quickly through the air, it smokes and gives out an unpleasant smell, because the temperature of the flame is so much lowered, that it can no longer consume all the carbon, or all the vapour, of the decomposed tallow, wax, or oil.

CAMPHINE, or rectified oil of turpentine, is a compound very similar to naptha. It contains no oxygen, and the amount of carbon, as compared with its hydrogen, is so great, that no ordinary wick would effect its combustion. But by the application of the principle of the Argand-burner, and the use of a chimney-glass, sufficient air can be supplied to the circular wick, to cause the production of the most brilliant and most perfect light for ordinary purposes with which we are acquainted.

QUESTIONS TO CHAPTER II.

What is the name of the chief supporter of combustion? Is there always heat where there is light? In ordinary cases of combustion is air present? Can the temperature be fixed at which combustion takes place? Why do the products of combustion usually escape notice? What are the elements which compose our chief sources of artificial light and heat? When carbon unites with oxygen, what is the source of heat?

Is a chemical compound always definite in composition? Has carbonic acid, for instance, always the same composition? Is there any law of chemical combination? Recite what you know.

Is carbonic acid the only compound of carbon with oxygen? What is the name of this second compound? What are its properties? Its composition?

What do we mean by the term combining proportion? Has the word equivalent the same meaning? By what sign or symbol is the name of an element expressed by chemists? What do the initial letters C, O, N, H, stand for?

Is hydrogen an important source of heat? What compound does hydrogen form with oxygen?

What is the meaning of the word atom? Can you give an intelligible explanation of the atomic theory?

What are the two gases which are capable, when admixed and inflamed, of giving out the greatest amount of heat?

Is pure gaseous matter capable of giving out light? Give an instance.

In what gas do bodies burn most brilliantly? When oxygen unites with elements in more than one proportion, how do we distinguish them? When oxygen is abstracted from an element, what do we call the process? Can a body be destroyed? Can you give an instance in which the product of combustion is visible?

What is the supposed origin of coal? Does it differ much in appearance and composition? What are the elements of pure coal? Upon what does its value as a light-giving agent depend? Is nitrogen ever present in coal?

Of what does coal-ash consist? What is the worst constituent coal can have?

Who is the supposed discoverer of coal-gas? When was London first lighted with gas? Give a brief description of its manufacture. What coal gives the largest amount of gas? What is the general name by which the light-giving compounds are known? What is the name of the gas which constitutes the chief bulk of coal-gas? What are its properties? Why is it called marsh-gas? Has Will-o'-the-Wisp any of the characteristics of this gas? How does Will o'-the-Wisp kindle itself?

What is the most important constituent of coal-gas? What is the origin of its two names? What is its luminosity owing to? What does a luminous flame always contain? How can the presence of a solid in flame be proved? What is the cause of the light of most flames? Explain the kind of combustion which goes on in a gas-flame? How can we obtain the brightest light from gas? What is the Bude light?

What is the nature of fire-damp? How did Sir H. Davy contrive to diminish the danger to which miners are exposed? Upon what principles is the Davy-lamp formed?

Why must coals be heated before they will inflame? How is it accomplished? Explain the chemistry of a coal-fire. Is air essential to the combustion of coal? What does smoke arise from? What is the temperature of a red-heat?

What may wood be said to consist of? How is charcoal prepared on a large scale?

What is wax? Where is spermaceti found? What are wax and spermaceti composed of?

Whence is tallow obtained? What is stearine? What is its more appropriate name? Give some information about glycerine. Is margarine a compound of tallow? Whence is its name derived? What does oleine most abound in?

Upon what does the consistence of oils and fats depend?

Why is a wick essential to the complete combustion of tallow, wax, oil, and such like? Explain its action.

Describe the flame of a candle. What is the difference between the oxydizing part of the flame and the deoxydizing?

What is camphine?

CHAPTER III.

CHEMISTRY OF THE BREAKFAST-TABLE.

IN speaking of the various substances which appear on our breakfast tables, I propose to confine myself to **WATER**, and the various decoctions which are made with it; **SUGAR**, which sweetens our **TEA**, **COFFEE**, or **CHOCOLATE**; **MILK**, which makes it more nourishing and palatable, with its products, **BUTTER** and (incidentally) **CHEESE**; **FLOUR**, from which our bread is made, and **EGGS**, which form so agreeable and nutritious an addition to our morning meal. **MEAT**, **PRESERVES**, and other accessories at our breakfasts, must be reserved for the Chemistry of another meal which will hereafter occupy our attention. We shall proceed at once to a further consideration of that (so-called) element, on which depends so much of the comfort of our morning repast—**WATER**.

How marvellously useful, and correspondingly

abundant, is water! The sea covers nearly three-quarters of the earth's surface; in the form of brooks and rivers water flows through the land in almost every direction; it rises at all times as vapour into the air, forms clouds, and again descends to the earth in rain or dew.

Water solidifies in the form of ice at 32° F. Its specific gravity is *less* than that of water. The specific gravity of water is 1.000, that of ice 0.920. The latter therefore swims upon the former.

The property of all liquids, except water, is to contract as they cool. However unimportant this exception may at first appear, our admiration must be greater when we reflect upon its consequences. Were it not for this, the very climate of our country would be changed! We know the freezing of water to be due to the coldness of the air; consequently, the upper part of the water is colder and heavier, and sinks to the bottom. If the water became continually denser, to its freezing point, the circulation of the heavier water to the bottom, and the lighter to the top, would continue till the whole mass of water had reached the ice point; a cold day would then suffice to turn our rivers and lakes into ice. This does not happen, because water, at a temperature below 40° F., expands, becomes lighter, and floats. Thus freezing can only take place at the surface, and ice be but gradually formed. At a small depth below the ice, water retains the tem-

perature of 40°. Water is accordingly most dense at 40°. It is slightly compressible, but only under very great pressure.

Another striking property of water is its solvent power. Very many solid substances are capable of uniting perfectly with it. Thus, when sugar is put into water, it dissolves, and a solution of sugar is obtained. Whenever solution takes place, the water possesses the taste of the substance dissolved. Thus the solution of sugar is sweet; and if the water be driven off by heat (evaporation) the solid substance may be always recovered. Owing to this solvent power, water, as it passes through the earth, takes up many solid substances which more or less injure its purity. The distinction between *soft* and *hard* water has reference to its greater or less degree of purity; river water is softer than spring water; spring water than sea water. The most abundant of all the substances extracted by water from the earth is common salt; hence we find it in springs and rivers, as well as in the sea. There are, of course, different degrees of saltiness even in the sea. Owing to the great heat, the water at the equator contains more salt than the English Channel; although evaporation (passing off in vapour) is going on constantly all over the ocean. The presence of salt in the sea renders it more buoyant than common water.

But more especially is the hardness of the water due to salts of lime. When much gypsum is con-

tained in water, it is deposited by evaporation in kettles and pans, and is said to *slate* them. When, however, the lime is contained in form of carbonate of lime or chalk, this is also deposited at the boiling point, and is said to *furr* them.

Gases are also taken up by water. Thus, of the gases already described in this book:—

One volume of water absorbs—

	Volumes of Gas.
Of ammonia . . .	670.000
Of nitrogen . . .	0.025
Of hydrogen . . .	0.020
Of oxygen . . .	0.037
Of carbonic acid . .	1.000
Of carbonic oxide . .	0.015

Rain, therefore, in passing through the air, absorbs (*absorbeo*, I suck up) some of its constituents. If rain water be heated, the air will be seen to escape from it in bubbles. Here, again, is seen the importance of this solvent power, it being by the vital air or oxygen thus absorbed, that fishes are able to live in that medium.

If water be exposed to heat in open vessels, it boils, or is converted into steam, at a temperature of 212° F. If the heat be continued, the whole of the water will evaporate, leaving all solid impurities at the bottom of the vessel. When the process of evaporation is so conducted, that the vapour is cooled down or condensed drop by drop, we obtain *distilled* water.

As we have already seen, water is a definite compound of one equivalent of oxygen with one of hydrogen. Its formula is therefore HO . It may easily be proved not to be an element.

For instance, if we pass steam over iron filings heated to redness in a gun-barrel, a gas escapes (hydrogen), which burns with flame, and the iron filings are found, if the process be continued long enough, to be converted into red oxide of iron, or iron rust. Again, if we pass a stream of hydrogen over iron-rust heated to redness, we obtain pure water.

It will be necessary to point out a distinction which it is of great importance to bear in mind. Most vegetable and animal substances contain a large amount of actual water: but they likewise frequently contain many other compounds, in which oxygen and hydrogen are united *in the proportions* in which they are found in water. Not that these compounds *contain* water, but they can be compelled *to form* water, by destroying their organization! When, therefore, a compound is spoken of as containing the elements of water, I trust the meaning of the expression will be intelligible.

The purer or softer the water, the better it is adapted for making decoctions of tea, coffee, or cocoa. Should, however, water be particularly hard, a little carbonate of soda added to it, will, by removing the lime, much improve it. For the pre-

paration of a good cup of tea, coffee, or cocoa, it is absolutely essential that the water boil.

And first let us speak of TEA.

To give some idea of the nature of the plant, I need but tell you that it belongs to the same natural family as the well-known and beautiful plant, *Camellia Japonica*, and that the full-grown tea-plant has a very similar appearance. The flower is not unlike that of the myrtle. China is the father-land of the *Thea Sinensis*, as the chief species is called by botanists. I do not purpose entering upon a minute description of the various modes of preparing the tea before it is imported into England: it will be sufficient to mention that the different kinds of tea depend upon—the age of the plant, the parts which are used, the season in which the leaves are gathered, and their more or less careful preparation. Its leaves are gathered from one to four times during the year, according to the age of the tea. There are commonly three periods of gathering. The earliest gathered leaves are of the most delicate color and aromatic flavor, with the least portion of fibre or bitterness. Leaves of the second gathering are of a dull green color, and not so valuable; while the last collected are still inferior, and of a dark green.

As soon as the leaves are gathered, they are put into wide shallow baskets, and placed for some hours in the air and sunshine. They are then exposed to

the heat of a stove, stirred about quickly, and swept into baskets. They are afterwards rolled between men's hands, and subjected to a lower degree of heat. The tea is now placed on a table, that all unsightly leaves may be removed, and the appearance of the whole may be as favorable as possible. Some fine sorts of tea are rolled leaf by leaf into balls.

Tea was first introduced into Europe by a Russian embassy at the commencement of the seventeenth century. The yearly production of tea now amounts to 500,000,000 pounds.

More than one half of the weight of tea-leaves consists of *woody fibre*; a substance insoluble in water, and without a particle of nutriment. The black teas contain more of this fibre than the green. They sometimes contain as much as sixty-five per cent.

If to a decoction of tea, a solution of a salt of iron is added, the mixture turns black as ink. This well-marked property is owing to a peculiar principle, to which the name of *tannin* has been given, because it is essential to the conversion of the skin of animals into leather. The astringent flavor of tea is owing principally to this tannin, of which green tea contains as much as $8\frac{1}{2}$ per cent. As a rule, the longer tea stands, or, to speak more correctly, the longer it is in contact with boiling water, the more astringent does it become. At the same time, a large amount of *extractive* is drawn out

of the tea, and renders it stronger; but, inasmuch as its fragrance is owing to the presence of a volatile oil, the longer the tea is allowed to draw, the less pleasant becomes the taste.

The name *extractive* is one commonly given to all the innumerable vegetable substances not thoroughly examined, which possess a more or less dark color, and do not crystallize. Extractive is soluble in water, and generally possessed of the taste and the medicinal effect of the plant from which it has been taken. It is usually distinguished as bitter extractive in aloes, as sweet in liquorice, and so forth.

Thein, the peculiar principle of tea, crystallizes in fine white prisms of a silky lustre. It is a definite compound of carbon, nitrogen, hydrogen, and oxygen. Its formula is $C^8 N^2 H^5 O^3$. When common tea-leaves are placed on a watch-glass, loosely covered with blotting-paper, and heated on a hot iron plate gradually to the point at which browning takes place, long white shining crystals appear on the paper and on the surface of the leaves. This is *thein*.

To make a good decoction of tea, M. Soyer recommends heating the tea in a dry tea-pot, before the hot water is added. Be this as it may, only a small portion of boiling water should be poured on the tea, until the leaves have become fully expanded, and not until then should the remainder of the water be added. From three to five minutes is long

enough for the tea to *draw*. All that is really good for health will be extracted in that time.

We will now speak of **COFFEE**. It belongs to the same natural family as ipecacuanha, quinine, and the plant from which Turkey-red is obtained. The *Coffea Arabica*, the coffee plant, will, however, be admitted to be the head of the family. It is a native of the Ethiopian highlands, but is now extensively grown in Arabia and the East and West Indies. It grows to a height of sixteen feet; the flowers are white and fragrant, but fade rapidly. The fruit somewhat resembles the cherry, and grows, like the flowers, in clusters; when ripe, it is shaken from the tree, and laid on mats exposed to the sun; and when dry, it is spread upon the floor, and the husks are broken off by a heavy roller. The berries are then winnowed and further exposed to the sun. Each plant will yield from one to two pounds. Coffee was first introduced into England in the year 1652.

Coffee contains about 70 per cent. of woody fibre. The *coffee-bitter*, or extractive, is a brown transparent extract, soluble in water, and having the characteristic bitter taste of the raw coffee bean. The coffee beans also contain gum and resin, and a small quantity of a fragrant oil.

Caffein is the principle which characterizes coffee. It is analogous in composition to *thein*, and consists of carbon, hydrogen, oxygen, and nitrogen, in definite proportions. It forms white silky crystals, so-

luble in boiling water. It is very volatile, and is best obtained from coffee-roasters on a large scale.

According to Cadet, coffee, if roasted to a pale brown color, loses 12·3 per cent., if to a chesnut-brown, 18·5 per cent. in weight.

The *flavor* of coffee, as a beverage, depends upon the *roasting* and the mode of *making* the infusion. The coffee should be mixed with a little brown sugar, and well, but rapidly, roasted in close vessels. It should be ground into fine powder immediately before it is required for use. Should the coffee beans have been roasted some time, the flavor of the infusion will be much improved by re-roasting them for a few seconds. The best coffee can only be obtained from freshly-roasted beans.

Opinions vary as to whether the coffee should be boiled or infused. If an agreeable flavor be desired, the more quickly the boiling water filters through the finely-ground and freshly-roasted coffee, the better. It is, however, necessary to use a larger quantity of coffee in this case, than when it is boiled. Boiled coffee is darker coloured, contains more bitter extractive, is less fragrant, and more acid than infused coffee, and is, moreover, apt to be thick. A little isinglass will, however, quickly clarify it.

“Persons of weak or sensitive organs will perceive, if they attend to it, that a cup of strong coffee after dinner instantly checks digestion. It is only when the absorption or removal of it

has been effected, that relief is felt. For strong digestions, which are not sufficiently delicate reagents to detect such effects, coffee after eating serves, from the same cause, to moderate the activity of the stomach, exalted beyond a certain limit by wine and spices. Tea has not the same power of checking digestion."—*Liebig's Letters*.

COCOA. — The cocoa tree (*Theobroma cacao*) grows wild in several countries of the torrid zone of America, especially in Guiana, Mexico, and on the coast of Carraccas. The fruit is a large coriaceous (leathery) capsule, (having nearly the form of a cucumber,) the seeds of which furnish the buttery, slightly bitter substance, called *cocoa*. It is now cultivated chiefly in Central America, and in British, French, and Dutch Guiana. In the West India Islands, the cultivation of cocoa has given place to that of sugar and coffee.—*Johnston's Physical Atlas*.

Cocoa contains an oil or vegetable butter or fat, which is white, of a peculiar odor, and of the consistency of tallow. It consists chiefly of *stearine* (from *στέαρ*, stear, fat), and *elaine*, or *oleine* (from *ελαιον*, elaion, oil); it is, therefore, in composition very similar to tallow. This fat disagrees with many people, but it may be easily removed if the cocoa be prepared over night; the solid fat being skimmed off in the morning, before it is boiled over again. What is called *homœopathic cocoa* is entirely freed from fat.

Cocoa, like tea and coffee, contains a principle peculiar to itself. This principle is similar to caffeine, having the same taste. *Theobromine* is a white crystalline substance. Its formula is $C^8 N^2 H^6 O^2$. It may be prepared indifferently from cocoa or chocolate. The latter contains sugar, and frequently flour or starch, intimately admixed with the pounded nuts. It forms a wholesome and very nourishing aliment, especially valuable to travellers. In the early Spanish colonies of America, chocolate was considered, not as a luxury, but as a necessary article of sustenance. Of tea, coffee, cocoa, and chocolate, the two latter can alone be said to be nutritious. That term cannot be applied, in any degree, to coffee or tea. But what is very curious in these beverages is, that they all contain principles so similar in composition. For, although *theobromine* differs from *theine* and *caffeine* in some respects, yet these principles occur only in beverages employed for the purposes of refreshing and gently stimulating the system. Liebig has shown all three to be closely related to *taurine*, a principle in the bile; and what renders the opinion of this sagacious chemist more probable is, that they all contribute to the formation of bile.

SUGAR is the next article which must engage our attention, as it is employed to sweeten all our morning beverages.

The sugar-cane (*saccharum officinarum*) supplies

us with sugar. Before the time of the Crusades sugar was cultivated in Europe, and, though on a very small scale, it is still grown in Valencia and Granada. The plant was found growing wild in many parts of America, at the time of the discovery of that country by Columbus; and it has flourished on the coasts of China, and in the islands of the Pacific, from the remotest ages. The produce of certain districts, however, are of especial importance for the supply of Europe. These are, in the New World, the West India Islands, Guiana, and Brazils; in the Old World, Mauritius, Bourbon, Bengal, Siam, Java, the Phillippine Islands, and China. (Johnston). Cane-sugar occurs likewise in the juice of the maple, of beetroots, carrots, turnips, potatoes, and in the nectaries of most flowers.

The cane, when ripe, is cut off at the root, stripped of its leaves, and passed twice through the mill, for the purpose of expressing the juice. To prevent fermentation, a portion of lime is mixed with the juice, which is then quickly evaporated in boilers. As soon as it is found, on trial, to be sufficiently evaporated, it is transferred into large, flat pans, or coolers; here the crystals soon separate from the *molasses* or *treacle*, the latter being nothing else than a concentrated solution of uncrySTALLIZABLE sugar. The sugar itself is packed into hogsheads, and brought to this country, under the name of *muscovado* or *raw sugar*.

The process of refining consists in removing the colouring matter and other impurities from the raw sugar. A strong solution of the latter is made in water, and the serum of blood, or white of egg, is added. Now I need scarcely mention that white of egg, when heated to a certain extent, becomes solid; and as the serum of blood also contains *albumen* like white of egg, and the one cannot be distinguished from the other, they may be employed indifferently for the same purpose. On applying heat, the albumen curdles and forms a complete network, which rises to the surface, carrying all solid impurities with it. This is skimmed off, and the sugar solution filtered through animal charcoal, which entirely removes all color. It is then quickly evaporated in a vacuum, or at least under greatly-diminished atmospheric pressure, by which means, exposure to a temperature sufficiently high to injure the sugar is avoided. As soon as the sugar is capable of being drawn into threads, it is carried to the *coolers*, and agitated with wooden oars till it granulates. Upon this agitation in the cooler, the whiteness and fineness of grain in the refined sugar depend. While the sugar is in this state, it is poured into conical earthen moulds, closed at the apex of the cone, a small hole, however, being left, into which is inserted a paper plug which has previously been soaked a night in water. When these moulds are sufficiently cold, the paper-

stops are removed from the points of the moulds, which are set, with the broad ends upwards, upon earthen pots, to drain. As soon as the uncrystallizable syrup has been drained off by various processes, the *sugar-loaf* is baked in an oven, heated to a temperature of 95°.

In making *sugar-candy*, the boiled sugar, instead of being put into coolers, is poured into pots, across which threads are strained; to these threads the crystals attach themselves; the pots are then set in a stove, great care being taken not to disturb the liquid, as upon this depend the largeness and beauty of the candy. (Brande). *Barley-sugar* is nothing more than melted sugar.

These lumps of sugar, or the brown sugar, which we consume at our breakfast-table, of what do they consist? Chemistry offers this simple solution. Pure sugar is *charcoal* (carbon) combined with the elements of water. Of the presence of carbon you may easily satisfy yourselves. Take a lump of sugar, moisten it with hot water in a tea-cup, and pour some drops of oil of vitriol (sulphuric acid) upon it. It will immediately blacken and swell; great heat will be evolved, and the lumps of sugar be resolved into a lump of *charcoal*. (You must, however, be careful not to touch it with your fingers, until it has been thoroughly washed in water, and all the acid removed from it). The cause of this change is, that oil of vitriol, having

very great attraction for water, compels the elements of water contained in organic substances to unite, in order to satisfy this propensity. The formula of crystallized cane sugar is $C^{12} H^{11} O^{11}$.

I trust I have succeeded in conveying a clear idea of all that is necessary to your comprehension of the nature of sugar and of its manufacture. But besides the treacle to which I have alluded, there is another description of sugar, which we sometimes use to spread upon bread. You will of course understand me to speak of HONEY. Now, cane-sugar is found in the nectaries of flowers. This is collected by bees, and by them converted into *honey* and *wax*; that portion of the sugar which is not required for nutriment, the bee returns into the combs, in the form of a yellow syrup, the smell and taste of which varies according to the nature of the flowers from which the bees have obtained the sugar. Honey contains two kinds of sugar. The solid, granular part of the honey is of the same composition as *grape-sugar*. The latter may be best seen in old raisins, which are commonly covered with its crystals. A more correct name than *grape-sugar*, however, is *glucose*, or *sugar of fruit*, because it is the sweetening principle of all kinds of fruit, and not of the grape alone. In composition it differs from cane-sugar only in containing a larger quantity of the elements of water in chemical combination. Its formula is $C^{12} H^{14} O^{14}$. The liquid

part of the honey contains an uncrystallizable sugar. In addition to these, honey contains—a yellow coloring matter, wax, and gum.

The next object on the breakfast-table, that demands our attention, is MILK. It is of great importance, its composition being such, that it is capable of supporting animal life, without any other food. It varies much in quality, according to the nature of the fodder on which the animal is kept. The more active the exercise taken by the cow, the smaller is the per centage of butter, and *vice versa*.

To the naked eye, milk appears to be a uniformly white solution. But this is an optical illusion. Under the microscope, it is seen to consist of a perfectly transparent fluid, in which float about numbers of transparent globules of fat. These, by reason of their lightness, have a tendency to rise to the surface, where they collect, and in time form a film or layer of a different character from the fluid beneath; this film or layer is the *cream*, the subjacent liquor the *skim-milk*. This separation appears to take place most completely in a cool temperature, from 54° to 60° F.

Milk is, in fact, a natural *emulsion* or mechanical mixture of fatty and other matters with a watery solution.

BUTTER is obtained from cream by churning. By agitation, the fatty globules cohere and sepa-

rate from the watery portion in larger or smaller lumps. The fluid which remains is the *butter-milk*. In the course of the agitation which the cream undergoes in churning, the delicate, elastic, transparent pellicles which surround the globules, give way, and the globules of oil, fat, or butter, being no longer prevented by the skin, are left free to cohere. The time required for the process is dependent upon various circumstances. In summer a cool, in winter a warm place is chosen for the operation. On being taken out of the churn, the butter is kneaded and pressed, and washed under water, in order to free it as much as possible from the buttermilk and curd which it always contains, and to the presence of which is to be ascribed the speedy alteration which butter undergoes in warm weather.

The fatty matter which constitutes the *chief* part of the butter, consists of materials similar to those of other fats, viz., of *margarine* and *oleine*. *Margarine* gives solidity to the butter. In summer the *oleine* predominates, and the butter is consequently less firm. In winter the *margarine* predominates, which, in conjunction with the lower temperature, makes it comparatively hard. *Butyrine* is an oily substance, amounting to about three per cent., and gives the tasty principle to the butter. This is very liable to become sour and to be converted into *butyric acid*, which makes butter become rancid. Its formula is

$C^8 H^7 O^3$. It may, however, be removed by repeated washings with hot water.

Butter also contains certain other *acids* in minute quantities, known by the name of *capric*, *caproic*, and *caprylic* acids. Butter is usually salted in order to make it keep. It may be preserved quite fresh for a long time, by covering it with syrup, without the addition of any salt, and the syrup may be washed off it when the butter is required for use.

The water of milk holds in chemical solution a considerable per centage of curd, or *caseine*. Fresh milk contains, in solution, nearly one-half per cent. of soda, which has the property of dissolving the curd. It serves for the formation of the blood, and for the nutrition of the animal tissues. *Cheese* is a mixture of caseine with a greater or less quantity of butter.

When fresh milk is allowed to stand for some time, the lighter suspended particles rise, and form *cream*. When kept for five or six days, at a low temperature, it evolves nearly the whole of its cream, and underneath is found a liquid resembling milk and water. According to Berzelius, cream consists of—

Butter	4·5
Caseine	3·5
Whey	92·0
<hr/>	
	100·0

Milk, when left to itself, as every one knows, becomes sour, and curdles. This is owing to the fact, that the *sugar of milk* (*lactine*), which gives sweetness to it, becomes converted into an acid. This *lactic acid* combines with the soda, which holds the caseine in solution; and, as the latter is insoluble in water, the milk is converted into *curds* and *whey*.

Sugar of milk is an important constituent of milk; it is obtained in large quantities by evaporating *whey* to a syrupy state, and purifying the lactine, which slowly crystallizes out, by animal charcoal. It forms white crystals of great hardness. It is difficultly soluble in cold water, requiring for that purpose six times its own weight; it has a feeble sweet taste, and feels gritty between the teeth. Its formula is $C^{12} H^{12} O^{12}$.

After the cream has been removed, there still remains a large per centage of cheese, as the following analysis of skim-milk will show:—

Water	92·87
Curd, caseine or cheese .	2·80
Sugar of milk	3·50
Ash	0·83

Skimmed milk will, therefore, likewise curdle on exposure to air. The whey still further contains a substance similar to white of egg, and various salts. The latter consist chiefly of phosphate of lime and magnesia (bone earth), common salt, and a salt of

potass. The composition of fresh cow-milk will now be intelligible. It consists of, in 1000 parts—

Water	873·00
Butter	30·00
Caseine	48·20
Lactine	43·90
Phosphate of lime and magnesia .	2·73
Phosphate of iron	0·07
Chloride of potassium	1·44
Chloride of sodium	0·24
Soda, combined with caseine . .	0·42
	<hr/>
	1000·00

These few remarks will have enabled us, in some degree, to appreciate the value of milk as an article of food.

Having devoted so much of our attention to liquids, let us now turn to the consideration of the more substantial articles of consumption at the breakfast-table; and BREAD, as the most important, first claims our notice.

The valuable grain which we call *wheat*, is the produce of several kinds of the genus *triticum*, winter wheat and spring wheat (*triticum hybrynum* and *triticum æstivum*), being the most common. Wheat, like rye, oats, barley, and rice, belongs to the natural family, *graminaceæ* (grasses)—a family which includes some of the most useful and the longest cultivated plants in Europe. Many

indications, botanical as well as historical, warrant the presumption, that Tartary and Persia are the native countries of wheat, rye, and oats; this, however, is uncertain.

In wheat, rye, &c., *starch* constitutes the principal part of the grain. Indeed, next to wood, starch is the most abundant product of the vegetable kingdom, and from it the wood itself is formed. To obtain starch from wheat, the grain is either coarsely ground, and mixed with water in large tubs; or it is put to steep in sacks, until it becomes so soft, that the process of kneading suffices to set the starch at liberty. It must not, however, be supposed that *ordinary* starch is prepared from wheaten flour, though it may be made from it in the manner described. On a small scale, starch may be obtained from wheat, by mixing up dough with water, and washing it on a linen cloth with water. A milky liquid passes through, which, when set aside, deposits a white powder. *Sago*, *tapioca*, *cassava* and *arrow-root*, consist, for the most part, of starch, and form a light wholesome food. Pure starch is a white substance, half-again as heavy as water, and insoluble even in boiling water, in which it becomes thick and gelatinous, having the *appearance* of solution, owing to the bursting of the little sacs in which each granule is enveloped. In composition, starch differs but little from, and is very easily converted into, grape-sugar. This will be

more readily perceived by comparing the composition of both:—

	C.	H.	O.
Grape sugar . . .	12	14	14
Starch	12	10	10

Thus, by combining with four atoms of the elements of water, this change is effected. An infusion of malt in a solution of starch, kept for some time at 150°, will produce this change, as we shall see in the process of brewing.

Starch, from its ready convertibility into sugar, is well adapted for carrying on those changes which occur in the juices of vegetables; and stored up, as it is, in the seeds, roots, and pith of plants, it supplies, by its decomposition, the materials for many of the most essential vegetable products. It furnishes, likewise, an important article of food for animals. It does not serve to increase the bulk, but supplies the material for keeping up respiration, and the animal heat of the body. The fat of man and animals is, in all probability, derived from starch. The average per centage of starch is as follows:—

In Wheat flour . . .	39 to 77
„ Rye flour	50 to 61
„ Oatmeal	70 to 80
„ Rice flour	84 to 85

The most important nutritive element of wheaten bread is the *gluten* which it contains. This is ob-

tained, with great facility, by simply kneading a mass of dough under a small stream of water, by which the starch, as before described, is carried off, leaving in the hand a greyish, glutinous, highly-elastic substance—the *gluten* of chemists. It is a true vegetable *fibrine*. The adhesiveness of gluten is owing to the presence of a very sticky substance, called *gliadine*.

The washings, collected and allowed to stand, soon become clear; the starch which was suspended in the liquid subsides, accompanied by flakes of an *animalized* matter. If the clear liquor be decanted and boiled, a *white froth* appears upon its surface, which, when skimmed off, has the appearance of coagulated *white of egg*, and possesses the same properties, as well as the same composition. The water from which the *albumen* is separated, contains all the still *soluble* portions of the flour. On evaporation, we find substances resembling *gum* and *sugar*, together with *saline matters*. These latter aid in the formation of bones. The following indicates the per centage of elements in the *gluten*, *fibrine*, and *albumen* of wheaten flour:—

Carbon	53·5
Hydrogen	7·1
Nitrogen	16·0
Oxygen, Sulphur, and Phosphorus	23·4
	<hr/>
	100·0

Including all the nitrogenized substances of the grain of wheat under the head of *gluten*, we find it to vary from eighteen to even as much as thirty-five per cent. of the whole. Twenty per cent. may be considered a fair average.

In making bread in the ordinary way from wheaten flour, the yeast added to the dough changes the sugar, which, as we have seen, the flour naturally contains, into *alcohol* (spirits of wine) and *carbonic acid gas*. The latter forces the tough dough into bubbles, which are still further expanded by the heat of the oven, which at the same time dissipates the alcohol.

Leaven is merely dough in a state of incipient putrefaction. When, therefore, it is mixed with a quantity of fresh dough, the same process of change takes place as when yeast is employed. It is, however, but little used at present, as it frequently communicates a disagreeable odour and a sour taste to the bread.

In making bread the starch is, *in part*, subject to a very extraordinary change. By the heat in the oven it becomes converted into *dextrine*, called also *British gum*, which is easily soluble in water, and therefore more digestible than starch. That this formation really does take place, may be easily proved by wetting, with a moist sponge, the exterior of a loaf of bread, and returning it to the oven. After a few minutes, the crust will be found

quite shining, as if covered with gum. The water has brought out a portion of the dextrine. In making *toast*, nearly the whole of the starch becomes thus changed, and a small portion of it, as well as of the gluten, is carbonized.

There are two great objections to the use of *white bread*. Frequently the preference given to very white bread leads the baker to the liberal use of alum. The proportion of alum used in a quarter loaf, is said to vary from twenty-two grains to three times that quantity. The baker is enabled to use an inferior flour, which thus assumes a very white appearance; and, owing to the property possessed by alum of absorbing and retaining water, a smaller amount of flour is necessary to make up the full weight of the loaf. The natural tendency of white bread to produce constipation is greatly increased by the use of alum. The removal of the *bran* renders the bread less nutritious. The bran is especially rich in phosphate of lime, or bone-earth, in fat, and in nitrogen. A man might live upon *brown* bread and water; he would languish and die upon white bread and water. For young children, indeed for all persons still growing, brown bread is incomparably superior to white. The prevalence of bad teeth among the English may be in part owing to their universal preference for white bread.

In the ordinary process of bread-making, considerable waste is occasioned by the *vinous* or *alco-*

holic fermentation, and several methods have been suggested to prevent it. The one recommended by "a Physician," is based upon the fact, that when carbonate of soda is mixed, in the proper proportion, with spirits of salt (hydrochloric acid), the common culinary salt, *chloride of sodium*, is formed; the carbonic acid, being set free, expands the dough so as to form bread. It is very necessary that the soda should be equally diffused through the flour, for if it be deficient in any part it will not rise there; and if in another part there be too much, or little lumps of it, in that place the bread will show a yellowish spot. The best mode of mixing it, is to shake the soda from a small sieve over the meal or flour with one hand, and stir them together with the other, and then to pass the mixture once again through the sieve. The acid should then be poured into the water, stirred and mixed intimately with the meal or flour and the water so prepared as speedily as possible, a wooden spoon being used for the purpose. The bread should be put into a quick oven without loss of time.

The prescription given by "a Physician," is as follows :—

TO MAKE WHITE OR FLOUR BREAD.—Take of flour three pounds avoirdupois; bi-carbonate of soda nine drachms; hydrochloric acid (specific gravity 1.16) eleven and three-quarter fluid drachms; water, about twenty-five fluid ounces.

TO MAKE BROWN OR MEAL BREAD.—Take of wheat meal three pounds; bi-carbonate of soda, ten drachms; hydrochloric acid (specific gravity 1.16), thirteen fluid drachms; water, about twenty-eight fluid ounces.

Another method of obtaining unfermented bread, is to mix sesqui-carbonate of ammonia with the flour. About half an ounce to the pound will, I think, suffice. The heat of the oven first volatilizes a portion of the carbonic acid of the carbonate, and then the rest of the carbonate of ammonia as such.

Bread made in the ordinary way is sometimes sour. This is owing to the formation of acetic acid (vinegar), and lactic acid (acid of milk).

Before concluding this part of my subject, I should mention that it is of great importance that bread be baked in an oven sufficiently hot to harden the sides of the cells (which are artificially formed by the escape of the carbonic acid), so as to retain their form after the loaves are removed. When bread is very rich in gluten, it requires greater heat than usual, in order to get rid of the excess of water. The more uniformly porous the bread appears after baking, the more wholesome is it, and *vice versâ*. Three pounds of flour usually retain, after baking, one pound of water. If alum be added, it will hold half a pound more water.

Having called attention to the nature of some of

the most important elements of the breakfast-table, we will now proceed to another. From what has already been said, we are now in a position easily to understand the nature of an Egg, and the change it undergoes in boiling. An egg-shell is of the same composition as common chalk. If spirits of salt (hydrochloric acid) be poured upon egg-shells, the whole, with the exception of a small amount of membrane, is dissolved, with effervescence arising from the escape of carbonic acid gas. On a close inspection of the shell, it will be found to be perforated in every part. These perforations or pores serve for the admission of air to the young bird during the process of hatching. The admission of air through them causes the egg, in time, to become rotten. The best mode of preserving them fresh, is to stop these pores by painting the eggs with lime, milk, or oil, and then to lay them in sawdust.

On breaking an egg we first meet with a colorless liquid, contained in cells; this is the *albumen* or *white of egg*. If it be dried at a temperature of 120° , it has the appearance of gum, and will be found to have lost seven-eighths of its whole weight. But if the heat be increased to 160° , the albumen coagulates, and is no longer soluble in water. Hence white of egg is described in two states.

1. *Dry soluble albumen*, when placed in water, first swells up, and then dissolves, forming a liquid of an opal tint. (This liquid has the property of

being coagulated by corrosive sublimate, with which it combines, forming an insoluble compound; and is in consequence the best known antidote to that most fearful poison. Four grains of corrosive sublimate are said to be rendered harmless by the contents of a single egg.)

2. *Coagulated albumen* yields from one to two per cent. of phosphate of lime (bone earth). Soluble albumen appears to possess the property of dissolving bone-earth, a property which enables the blood to convey to the bones their earthy parts (Liebig). Albumen contains both *sulphur* and *phosphorus*. The presence of the former causes the blackening of a silver spoon, when left in an egg for a short time, owing to the formation of *sulphuret of silver*.

When analysed, albumen is found to consist of carbon, hydrogen, oxygen, and nitrogen, with about one per cent. of sulphur and phosphorus together. It has the same composition as vegetable albumen. Its formula is $C^{400} H^{310} N^{50} O^{120} PS^2$.

The *yolk* of the hen's egg consists of white of egg, in which about thirty per cent. of a yellow oil is swimming. It coagulates when heated, owing to the albumen which it contains. The oil may be removed by strong pressure. In composition it resembles most oils, and consists of carbon, hydrogen, and oxygen in definite proportions, together with sulphur and phosphorus. It is of a bright yellow

color, and has a sickly smell. The only tasty principle of the egg, is the oil in the yolk.

When an ordinary-sized egg is boiled in water, it loses about three-tenths of a grain. Of an egg which weighs 1000 grains,

The <i>shell</i> constitutes	106·9	parts
The <i>white</i> „	604·2	„
The <i>yellow</i> „	288·9	„
	<hr/>	
	1000·0	

In a hard boiled egg, the albumen of the white and the yolk become insoluble in water, and less digestible.

Undoubtedly, the true starting-point of all the animal tissues is albumen. This appears from the phenomena of incubation, where all the tissues are derived from the albumen of the white and of the yolk, with the aid only of the air, of the oily matter of the yolk, and of a certain proportion of iron also found in the yolk. It is, therefore, clear from this, that albumen is capable of passing into fibrine, caseine, membranes, horn, hair, feathers, &c. (Liebig).

An attentive consideration of the various substances partaken of as food at breakfast, will suggest a division of them into two classes. We have seen that our food in some cases contains nitrogen, in others not. The caseine of milk, the albumen, gluten, and fibrine of bread, the albumen of eggs,

are substances rich in nitrogen, and serve to increase the mass of the human frame. Butter, sugar, sugar of milk, honey, starch, oil of eggs, are rich in carbon, and serve not only to maintain the animal heat of the body, but for the support of respiration and the formation of fat.

QUESTIONS TO CHAPTER III.

What are the names of the subjects of breakfast, of which this chapter treats?

At what temperature does water freeze? Of what nature is the exception which water forms to the rule that liquids contract as they cool? Why was the exception necessary? At what temperature is water most dense?

What is another striking property of water? What substances abound most in water? What constitutes hard and soft waters? Of the gases with which we are familiar, which is most and which least soluble? Is the solvent power of water important? How does it affect fishes? How may water be proved to be a compound?

What is meant when a compound is said to contain the elements of water? Is hard or soft water best for making tea?

To what family does the tea-plant belong? What country does it come from? How are the leaves prepared? How much tea is annually produced? How much woody fibre is contained in tea? What is tannin? What are its properties? What is meant by extractive? What is thein? How may it be prepared? Of what is it composed?

To what natural family does coffee belong? To what country? How is it prepared? How much woody fibre does it contain? Upon what does the flavor of coffee depend?

From what tree does cocoa come? What is the fruit like? What is the nature of the fat found in cocoa? What is the principal feature of cocoa? In what respect does chocolate differ from cocoa?

Where does the sugar cane grow? In what plants is cane sugar found? How is the cane prepared? In what does treacle differ from raw sugar? How is the refining accomplished? What is the object of blood in the purification? How is sugar-candy made? What is the composition of cane sugar? How may the presence of carbon be proved?

What of honey? What is the nature of sugar in honey? Is it peculiar to honey or to grapes? What is the name by which it is best known?

What renders milk of so much importance as an article of food? Is it a uniformly white liquid? What name would a chemist give to milk?

How is butter obtained? What is necessary to keep it fresh? Of what is it composed? What gives solidity to butter? What is the tasty principle of butter? To what is the rancidity of butter owing? What is the object of salting it?

What is cheese? By what name does the curd go? What keeps the cheese in solution in fresh milk?

When does cream form? What is it composed of?

Why does milk become sour? What is the sweetening principle of milk? What do chemists call it? What elements is it composed of? Why does skim-milk curdle?

From what plant is wheat derived? To what family does it belong? What is its country?

What constitutes the chief constituent of wheaten flour? How is it prepared? What are its properties? Does it differ much in composition from grape sugar? In what parts of plants does starch abound? What object does it serve in the human and animal economy? Whether does wheaten flour or rice contain most starch?

What is the nutritive element of flour? How may it be obtained? To what is its adhesiveness owing? What elements compose it? What is its average per centage in flour? What other compounds do we find in flour?

In making bread, what change does the yeast induce?

What is leaven? Why is it not more generally used?

What change does some of the starch undergo in baking? Does toast contain the same principle? What do chemists call it?

What objections are there to the use of white bread? What is the bran more especially rich in? How may unfermented bread be prepared?

To what is the acidity of some bread owing? Why should bread be well baked?

What is the nature of an egg? What is the shell made of? What is the chemical name of white of egg? What is its property? What is it composed of? In what does the yolk differ from the white? What proportion do the yolk, the white, and the shell bear to each other?

In what divisions may our food be classed?

CHAPTER IV.

ON THE CHEMISTRY OF FERMENTATION.

IT may be laid down as a general principle in Chemistry, that the more simple a substance is, as to its constitution, the more stable—that is, the less liable to decomposition, or to rearrangement of its parts—will it be, and *vice versâ*. The actual number of substances capable of undergoing *fermentation*, is exceedingly small, yet are they all most complex in constitution. In the chapter on Breakfast-table Chemistry all of them are incidentally mentioned; and, in fact, it is impossible to speak of the theory of *bread-baking* without entering slightly upon the subject of fermentation.

STARCH, CANE-SUGAR, and GRAPE-SUGAR are the compounds which are capable of *vinous fermentation*, that is to say, of undergoing a process in which spirits of wine, or alcohol, is formed, as is the case in making wine and beer. Even starch and cane-sugar must first be converted into grape-sugar before

they can ferment, and even the latter changes only under the influence of a so-called *ferment*.

It will be remembered that *grape-sugar* is not peculiar to the fruit of the vine, but that it is the sweetening principle of all fruits, and that *Glucose* (from *γλῦκος*, glukus, sweet), is the more appropriate designation. It is less soluble in water, and less sweet, than cane-sugar, and crystallizes in a different manner. A solution of perfectly pure grape-sugar in water, may be kept for a length of time, without the formation of any alcohol. But if it be mixed with white of egg, flour-paste, or blood, in a *state of decomposition*, then alcohol and carbonic acid will be formed at the expense of the sugar. Now, although neither alcohol nor carbonic acid are to be found in sugar, yet it contains the elements which constitute these substances. The composition of grape-sugar is:

Carbon	. . . . .	36·4
Hydrogen	. . . . .	7 0
Oxygen	. . . . .	56·6
		<hr/>
		100·0

Pure, or absolute alcohol, as it is called, and carbonic acid, *the bodies which are produced in the process of fermentation*, consist of—

	Alcohol.	Water.	Carbonic Acid.
Carbon	. . 52·19		27·27
Hydrogen	. . 13·02	11·1	
Oxygen	. . 34·79	88·9	72·73
	<hr/>	<hr/>	<hr/>
	100·00	100·0	100·00

One hundred parts of grape-sugar may, then, be said to consist of—

Alcohol	46·46
Carbonic Acid	44·45
Water	9·09
	<hr/>
	100·00

I have said that solutions of pure sugar cannot ferment, but in fact no such solutions exist in nature. The juices of all fruits contain *within themselves* the elements necessary for the production of vinous fermentation. Now, it may be fairly asked, what is understood by a *ferment*? It is a certain form of matter in a state of *change*, which it is capable of communicating.

All ferments contain nitrogen, and are in a state of decomposition. Fresh white of egg, for example, is not in itself a ferment; but when, by the action of the air, it becomes putrid, an alteration in its character takes place. Not only does it become changed in character, but it is capable of inducing a similar kind of change in compound bodies such as sugar, with which it may be brought into contact. Ferments are, therefore, contagious; or, in other words, capable of propagating their state of change. Fermentation is a process of change, occasioned by a new arrangement of the elements of a compound.

The name is derived from *fermentum*, that which is light and puffy; originally applied to the process

by which alcohol is formed in liquids containing sugar.

WINE.

The juice of the grape consists mainly of *water*, holding in solution—*grape-sugar*, *albumen*, (similar to white of egg,) *cream of tartar*, a *coloring matter*, an *oil*, and a small quantity of *tannin*. It is obvious, therefore, that grape-juice can ferment of itself. The proportions in which these various constituents of the juice exist in the grape, vary according to climate, culture, and the nature of the soil. Few crops are so much at the mercy of the atmosphere as the vine; even in the most favourably situated vineyards, it is rare that wines of equal quality and flavor are produced in two successive years. A hot summer is naturally favorable to the vine; but besides the sustained heat, which is necessary during the whole year's growth, it would appear that a mild autumn is a necessary condition to the ripening of grapes. The cultivation of the vine would be altogether ruinous, were it not for the circumstance that the value of wine increases in a much greater ratio than its quality, so that one good year often indemnifies the grower for many bad ones, and that the vine grows and thrives in situations where it would be difficult to rear anything else. The produce of a vineyard depends also upon its age.

Official documents, whilst they give the mean

produce of the vine, for the whole of France, at 171 gallons per acre, state the whole of the wine produced over the country at 976,906,414 gallons. The produce of the vineyards of the German States brought to market, appears to be 59,180,000 gallons. (Boussingault.)

In making wine, the *juice* of the grape is put into vats, or barrels, and left to itself. The *albumen* which it naturally contains, acted upon by the oxygen of the air, soon decomposes, and acts as a ferment upon the sugar. *Alcohol* is formed in the liquid, which becomes changed into wine, and *carbonic acid* is given off in such enormous quantities as to require some care in the overlookers. When fermentation has once set in, the access of air is not only no longer necessary, but is rather injurious than otherwise. In some countries the gas is passed, by means of a tube connected with the spunt of the barrel, into potash, or soda-ash, in solution, and thus, not only is the poisonous carbonic acid removed from the air, but a useful salt (the so-called bi-carbonate of potash, or soda) is obtained by its union with the potash, or soda.

I have said that grape-juice contains *cream of tartar*, a combination of two equivalents of tartaric acid and one equivalent of potash. This acid salt, which chemists call bi-tartrate of potash, though soluble in water, is insoluble in alcohol. As fast, therefore, as alcohol is formed, at the expense of the

sugar, does this salt separate in the form of a hard, crystalline substance, from which all the cream of tartar of commerce is obtained. In good vintages, when the *sugar* predominates, the formation of alcohol proceeds to such an extent, that the great bulk of the salt is removed; but in bad vintages much of it remains in the wine, rendering it *sour*.

Now, just as the juice of the grape contains an acid salt, so likewise does the juice of gooseberries, currants, and elderberries, from which home-made wines are prepared, though in them it is of a different character. The *malic acid* (from *malus*, an apple, because first discovered in apples) and the *citric acid* (from citrus, a citron or lemon) contained therein in combination with potash, are not affected by any quantity of alcohol, because they are equally soluble in water and in alcohol, and thus, however disguised with excess of sugar, these home-made wines are very unwholesome for many persons.

When the quantity of *sugar* predominates over that of the albumen or ferment, the result is a more or less *sweet* wine. But when the *ferment* abounds, the wine has a *dry* taste.

If the fermentation of grape juice be checked before it is complete, and the wine bottled, the process will be continued in the bottles. The carbonic acid gas being disengaged under considerable pressure, is retained in the wine, and thus are obtained those

delicious wines, Champagne, sparkling Moselle, Hock, &c.

The *coloring matter* of the grape resides in the *skins*. The *juice* of both red and white grapes is nearly colorless, because the coloring of the skin is not soluble in water. But it is soluble in alcohol. If, therefore, *red* wine is to be made, the expressed juice is allowed to ferment in contact with the skins, until the formation of alcohol has drawn out their coloring matter. The color of dark sherry is artificial, being derived from caramel, or burnt sugar.

The quantity of alcohol contained in wines varies. Port wine and sherry contain sometimes as much as twenty-five per cent., sometimes only sixteen per cent. The light wines of Germany and France contain from ten to fifteen per cent. Wine, like beer and spirits, as is well known, owes its intoxicating character to *alcohol*.

ABSOLUTE ALCOHOL, or PURE ALCOHOL, which may be obtained by distilling the spirits of wine of commerce with half its weight of quick-lime, is a colorless, limpid liquid, of an agreeable, though somewhat pungent, taste and smell. Its specific gravity is only $\frac{3}{4}$ that of water, being 0.793 at 60°. It possesses great attraction for water, absorbing it from the air, and from moist membranes or any similar substances immersed in it. It is miscible with water in all proportions. The strongest spirits

of wine of commerce contains upwards of thirteen per cent. of water.

The composition of alcohol is expressed by the formula $C^4 H^6 O + HO$; it is produced by the breaking up of one equivalent of glucose ($C^{12} H^{14} O^{14}$) into two equivalents of alcohol, four of carbonic acid, and two equivalents of water.

Strong alcohol, especially absolute alcohol, which is spirits of wine freed by means of lime from its water, acts as a poison when swallowed; but when diluted, it is, as is well known, stimulating and intoxicating.

Strong alcohol has never been frozen, even at a cold of $-212^{\circ}F.$; hence its adaptation for the making of thermometers by which great degrees of *cold* are to be measured.

Alcohol is highly inflammable, and burns with a pale blue flame. Next to water, it is the best solvent with which we are acquainted. And that it is largely employed as a means of solution will be apparent from the fact, that eau de cologne and the various perfumed waters, liqueurs and cordials, tinctures and varnishes, are solutions of the various oils, resins, barks, roots, and plants, in spirits of wine.

The conversion of alcohol into **ETHER** is a change of such importance, that it ought not to be omitted. It is formed by distilling equal weights of strong spirits of wine and oil of vitriol. The action of the

latter will be more intelligible, when we compare the composition of alcohol with that of ether.

The formula of alcohol is $C^4 H^6 O + HO$

That of ether is . . . $C^4 H^6 O$

Oil of vitriol has therefore taken the elements of one equivalent of water from the alcohol.

Ether is a colorless, transparent, fragrant liquid, very thin and mobile. Its specific gravity is 0.720. It is very combustible, and burns with a white flame, generating, like alcohol, carbonic acid and water. It boils at 96°. When dropped on the hand, it occasions a sharp sensation of cold from its rapid volatilization. It is miscible in alcohol in all proportions; but ten parts of water are required to dissolve one part of ether.

Ether resembles, in so many respects, the ordinary oxides of metals, that it is supposed to be the *oxide of an organic compound*, possessing properties similar to those of elements. This compound is called *Ethyle*, and is represented by the formula $C^4 H^6$ and the symbol Ae. According to this view, alcohol is a chemical combination of the oxide of ethyle with water, and, as definite compounds of water with other bodies are called *hydrates* (from *ὑδωρ*, hudor, water) so is alcohol *a hydrate of the oxide of ethyle*.

The bouquet of certain wines is due to the presence of an ether, the so-called *oenanthic ether*, from *οἶνος* (oinos) wine.

With reference to the use of wine, Liebig says, in his *Familiar Letters*: "As a restorative, or means of refreshment, where the powers of life are exhausted, of giving animation and energy where man has to struggle with days of sorrow, as a means of correction and compensation when misproportion occurs in nutrition, and the organism is deranged in its operations, and as a means of protection against transient organic disturbances, wine is surpassed by no product of nature or art.

"The nobler wines of the Rhine and many of those of Bordeaux, are distinguished above all others by producing a minimum of injurious after-effect. The quantity of wine consumed on the Rhine by persons of all ages, without perceptible injury to their mental and bodily health, is hardly credible. Gout and calculous disease are nowhere more rare. In no part of Germany do the apothecaries' establishments bring 'so low a price as in the rich cities on the Rhine; for there wine is the universal medicine for the healthy as well as the sick; it is considered as milk for the aged.

"Alcohol stands high as a respiratory material. Its use enables us to dispense with the starch and sugar in our food, and is irreconcilable with that of fat.

"Since the establishment of Temperance Societies, it was thought fair in many English families to compensate, in money, those servants who took the

pledge and no longer drank beer; but it was soon found that the monthly consumption of bread increased in a striking degree, so that the beer was twice paid for; once in money, and a second time in its equivalent of bread.

“On the occasion of the meeting of the Peace Congress in Frankfort, the proprietor of the celebrated Hôtel de Russie told me, with expressions of astonishment, that at his table at that time, a regular deficiency occurred in certain dishes, especially farinaceous dishes, puddings, &c.; an unheard-of occurrence in a house in which the amount and proportion of the dishes, for a given number of persons, has been for years fixed and known. This dining-hall was filled with friends of peace, all of whom belonged to temperance unions,—some, no doubt, to vegetarian societies—and drank no wine. Herr Sarg observed that those who take no wine always eat more in proportion. In wine countries, therefore, the price of the wine is always included in that of the dinner, and it is considered just, that in hotels people should pay for wine even when they drink none.

“‘O monstrous ! but one half-penny worth of bread to this intolerable deal of sack !’—SHAKESPEARE.”

CYDER AND PERRY.

A substitute for wine is found sometimes in the fermented juice of *apples* and *pears*. The fruit is

shaken from the trees, and piled up in large casks placed in cellars. It is crushed about two months after it is gathered, and the pulp is left for ten or twelve hours soaking in the juice, in order to give to the cyder that rusty yellow color, so much esteemed. The pulp is then pressed, and the juice allowed to run into large vats, in which it undergoes fermentation. After the latter process has proceeded for a month, the liquor is put into smaller barrels, in which the fermentation goes on more slowly. In time, longer or shorter, according to the temperature of the cellar, the whole of the sugar is changed into alcohol, and an agreeable, though, to some persons (for reasons which have already been pointed out) very unwholesome, beverage is obtained.

BEER, ALE, AND PORTER.

In the production of *beer*, the sugar is derived from the *malt*. Not that the barley contains much sugar, but, by a singular process, the starch passes into sugar. The operation of malting is performed by steeping the barley in water, until the grains become swollen and soft; and then piling it in a heap, to favour the elevation of temperature caused by absorption of oxygen. Afterwards it is spread upon the floor, and, from time to time, turned to prevent unequal heating. As soon as the sprouting of the seed has sufficiently proceeded, it is quickly

dried, to destroy its vitality. By this operation, the nature of the starch becomes altered; four times the amount of sugar, and three times the amount of gum, originally existing in the barley, are now to be found in the malt. This change has been accomplished by means of a substance called by chemists *diastase*, brought into action by the germinating of the barley. The composition of this substance is unknown; but that it partakes of the nature of albuminous substances, and contains nitrogen, is certain. It is likewise certain that the starch, which is formed when the vegetative power of plants is most active, is dissolved, and made ready for use by this very *diastase*, which exists in all seeds and buds.

If a little malt be infused in warm water, it will convert a very large amount of starch, first into soluble starch, or dextrine, and subsequently into sugar. To prove this fact, it is sufficient to mix some gelatinous starch with a small quantity of malt infusion, exposing the whole to a gentle heat. In a few minutes it becomes thin, like water, and, after a few hours, will be found to contain glucose, or grape-sugar, and to be sweet to the taste.

In the manufacture of *beer*, the malt, thus prepared, is ground and infused in the so-called *mash-tun*, in rather more than its bulk of water, of the temperature of 180°, and is exhausted by repeated washings with fresh portions of water. The easily soluble *diastase* has thus time to act upon the undis-

solved starch of the grain, and to convert it into dextrine and sugar. The liquor, strained from the malt-husks, is called *wort*. This is boiled with hops, by which the so-called *lupuline* (a bitter resinous principle), and an essential oil, are extracted. The hops serve to cloak the sweetness by a pleasant bitter,* and to give to the malt liquor more durable properties. When the wort has been sufficiently boiled, it is thrown into large, shallow *coolers*, in which it is cooled as quickly as possible; it is then suffered to run into the fermenting vat, having been previously mixed with a small quantity of *yeast*. This is a substance which collects, as a scum and sediment, during the fermentation of the wort, and is derived from the changes which the gluten and albumen of the malt sustain by contact with oxygen from the air. The addition of the yeast instantly induces *vinous fermentation*. A great amount of froth is thrown up, arising from the escape of carbonic acid gas; the liquor loses much of its sweetness; from being turbid, it becomes clear, and acquires a new taste and intoxicating properties from the formation of alcohol. The fermentation is stopped by separating the yeast, and drawing off the beer into casks.

Porter derives its colour from highly-dried, or

* The idea recently advanced that Messrs. Bass & Alsopp employ strychnine to communicate a bitter taste to their celebrated and wholesome ales, is too absurd to require refutation.

charred malt, the caramel of which communicates the colour. It contains about $4\frac{1}{2}$ per cent. of alcohol, while *Burton ale* contains as much as $8\frac{1}{2}$ per cent. *Small beer* contains but $1\frac{1}{2}$ per cent. of alcohol, and is a very wholesome beverage for the young.

ARDENT SPIRITS.

The chemistry of the manufacture of these is so similar to that of brewing, and, indeed, of the vinous fermentation in general, that little remains to be said. The distiller who prepares spirit from grain, uses a very large quantity of *grain* with the malt, the *diastase* of which converts the starch thereof first into dextrine and then into glucose. The wort, or *wash*, as it is called in the language of the trade, is brought to ferment as quickly as possible, by considerable doses of yeast, and is then distilled. *Whiskey* is prepared from barley and oats. *Highland whiskey* and *Irish poteen* seem to derive their flavour from the malt being made and dried with peat, which gives out minute quantities of *creosote* and *volatile oils*. *Rum* is obtained from the fermented juice of the sugar-cane. It must, however, be remembered that the *sugar* must first pass into *glucose* before fermentation can commence. *Brandy* (a word derived from the German, signifying burnt wine) is made from wine, and coloured with caramel, or burnt sugar. *Gin*, *Hollands*, and *Schiedam* are distilled from *barley*, and flavoured with juniper-

berries, turpentine, and other substances. The two latter spirits derive their names from the places where they are chiefly prepared. In Bengal and China, spirits are made from *rice*, a grain containing a larger amount of starch than any other natural product. *Arrack* is a spirit of this kind, and is characterised by the excessive amount of alcohol which it contains.

The amount of alcohol contained in gin, brandy, rum, and whiskey, varies from 40 to 50 per cent. The various flavors are due to essential oils, either generated by the act of fermentation or purposely added.

“It is an exception from the rule, when a well-fed man becomes a spirit-drinker. On the other hand, when a labourer earns by his work less than is required to provide the amount of food which is indispensable in order to restore fully his working power, he resorts to spirits. He must work; but in consequence of insufficient food, a certain portion of his working power is daily wanting. Spirits, by their action on the nerves, enable him to make up the deficient power *at the expense of his body*, to consume to-day that quantity which ought naturally to have been employed a day later. He draws, so to speak, a bill on his health, which must be always renewed, because, for want of means, he cannot take it up; he consumes his capital instead of his interest, and the result is the inevitable ruin of his body.”—*Liebig's Chem. Letters*.

Vinous fermentation may be induced even in milk, and a spirit is prepared from it in some few places. There is every reason for believing that the lactine, or sugar of milk, first passes into glucose before the alcoholic fermentation commences. Certain it is that the lactine disappears in milk exposed to a sufficient temperature, with the same phenomena as characterise the fermentation of the other sugars; carbonic acid is disengaged, and alcohol left in the liquid.

But every one knows that milk turns sour on exposure to air at the ordinary temperature. The caseine of the milk, by combining with oxygen from the air, passes into a state of decomposition, forming a ferment, which induces the so-called LACTIC ACID FERMENTATION. The acid which is found in the fermented juice of beet-root, carrots, and turnips, in sour-kROUT, and in several animal liquids, is nearly pure lactic acid. The *state* of decomposition in which the ferment exists, may induce either the lactic acid or the vinous fermentation. Thus, the glutino-albuminous matter of malt, when suffered to putrify in water for a few days, acquires the power of converting the accompanying sugar into lactic acid, while, in a more advanced state of decomposition, it converts the sugar into alcohol. And again, if wheaten flour be made into a paste with water, and left four or five days in a warm place, it becomes a *lactic acid ferment*; if left two

or three days longer, until it has become more putrid, it becomes true *vinous ferment*.

The formula of alcohol is $C^4 H^5 O + HO$. By oxidation, alcohol may be converted into *acetic acid* or pure *vinegar*. If, for example, a little yeast be mixed with dilute spirits, and *exposed to the air*, acetic acid will be the result. All liquids capable of the vinous fermentation may be made to produce vinegar. In all such liquors, the sugar is first, by fermentation, converted into alcohol, and afterwards, by oxidation, into acetic acid.

The process used to be called the ACETOUS, or ACETIC ACID FERMENTATION, but it has nothing in common with the vinous fermentation. The presence of air is absolutely essential to the former, while the latter may, when once commenced, be better carried on with exclusion of it. The nature of the formation of acetic acid from alcohol is very intelligible. It is formed from it by the substitution of two equivalents of oxygen for two equivalents of hydrogen. Thus—



Pure alcohol will no more become acetic acid by simple exposure to air, than will a solution of pure sugar change into alcohol and carbonic acid. A *ferment* is necessary, which only acts by the power it possesses of causing the alcohol to obtain oxygen

from the air. In fermented liquors, the alcohol being mixed with certain organic substances at a proper temperature, quickly disappears, and is replaced by acetic acid. In such cases the ferment absorbs oxygen from the air, and transfers it to the alcohol.

The best vinegar is made from *wine*. In wine-countries inferior wines are employed for the purpose. The wine is mixed with a little vinegar, and exposed to the air in casks, partly filled with the pressed husks of grapes. From time to time, the liquid is drawn off below, air supplies its place, the husks become warm by absorbing oxygen, which they yield to the alcohol when the liquid is again poured into the vessel. This process is repeated until the vinegar is made. Its strength may be indefinitely increased by the addition of more or less brandy to the wine.

Acetic acid is frequently manufactured by the so-called *quick vinegar method*. Casks, perforated to admit air, are filled with beechwood shavings, moistened with vinegar. A mixture of one part of spirits, five of water, and $\frac{1}{1000}$ part of yeast, or honey, is allowed to drop continuously through the casks: the temperature rises to 100°, and the whole of the spirit, by passing two or three times through the shavings, is, in 26 to 36 hours, converted into vinegar. Vinegar is also made from sugar, from beer, and from cider, by the aid of the various combinations of circumstances which have already been

mentioned. Free access of air, a temperature not below 85°, and the exposure of a large surface of liquid, facilitate the oxidation of alcohol, and the production of vinegar.

But besides the oxidation of alcohol there is another means of obtaining vinegar—viz., by the distillation of hard wood, as oak and beech, in iron cylinders. The flavour of *wood-vinegar* is peculiar, reminding one slightly of creosote.

Pure acetic acid is a clear, colorless liquid, very sour and pungent, and miscible in all proportions with water. The flavor of the best kinds of vinegar is due to *acetic ether*. The vinegars from wine, beer, and malt, contain, in addition to acetic ether, all the foreign matters pertaining to these various liquids. (Liebig).

It has been thought desirable to devote a separate chapter to the consideration of the Chemistry of Fermentation, partly because of the great interest it possesses as a branch of household chemistry, and partly on account of the important position which the manufacture of fermented liquors occupies in all civilized communities. From the earliest times of which we possess records, the application of the principle of fermentation to the preparation of beverages of more or less intoxicating qualities, seems to have been generally understood. Like all other gifts of God to His creatures, that of wine, "that maketh glad the heart of man," has been greatly

abused; nevertheless, though there are many philanthropists who would, on that account, entirely banish from society the use of all fermented liquors (with the exception, perhaps, of vinegar), it seems scarcely to admit of doubt that, used in moderation, they add materially to the reasonable enjoyment of mankind. At any rate, as long as they occupy the prominence among articles of consumption which they unquestionably do at the present day, a few pages devoted to their consideration can scarcely be thought out of place in a work like the present. The consideration of the chemistry of fermented liquors, moreover, will form a not unnatural introduction to that of the *dinner-table*, to which they form so general an adjunct, and which we propose to consider in our next chapter.

QUESTIONS ON CHAPTER IV.

What may be considered a general rule in chemistry? Is the number of fermentable substances great?

What are the names of the substances capable of vinous fermentation? What is necessary to cause them to ferment? Is grape-sugar peculiar to the fruit of the vine? What is the better name for it? What elements compose grape-sugar? Is alcohol contained in it? What bodies are produced in fermentation? What is understood by a ferment? What is its name derived from?

What is the nature of the change which grape-juice undergoes in fermentation? What use may be made of the carbonic acid resulting from the process? What is the chemical name for cream of tartar? How is it removed from good wine? In what does the difference between home-made and

other wines consist? How does a dry wine differ from a sweet one? How are effervescing wines prepared?

In what part of the grape does the coloring matter reside? Is it soluble in alcohol? From what source does the color of dark sherry arise?

Does the quantity of alcohol vary much in wines? How may it be obtained in a state of purity? Which is the heavier, water or alcohol? To what extent is it soluble in water? How many equivalents of alcohol are formed from one equivalent of glucose? Why is alcohol employed in constructing thermometers? Is alcohol inflammable? What is it employed in making?

What is ether made from? In what respects does it differ from alcohol? Is it soluble in water? To what chemical compound?

What is Liebig's general opinion of the use of wine?

What fruit is employed in making cyder and perry? Describe the process.

In the production of beer, whence is the sugar derived? Describe the malting process? What is diastase? Describe the process of brewing? What is the name of the bitter principle of hops? What is the name of the liquor strained from the wort? What is yeast? How are fresh supplies obtained?

From whence does porter derive its color? How much alcohol does Burton ale contain?

Is the chemistry of ardent spirits very dissimilar from that of beer? What do distillers use largely in addition to the malt? What name is given to the wort? From what is whiskey prepared? What gives the peculiar flavor to Irish whiskey? Whence is the name of brandy derived? What kind of spirit does the distillation of rice afford? Whence is rum obtained?

What is the amount of alcohol existing in gin, &c.?

What is the nature of the fermentation induced in milk? Into what kind of sugar does the sugar of milk pass before it ferments? What compounds are generated in the process?

What induces the lactic acid fermentation? What is the

difference between a lactic acid ferment and a vinous ferment?

How is alcohol converted into vinegar? What is the scientific name for vinegar? In what respects does the vinous fermentation differ from the acetic? Is the acetic a true fermentation?

What is the best vinegar made from? How is the process conducted?

Describe the quick-vinegar method?

Are there any other sources of vinegar?

What are the properties of pure acetic acid?

CHAPTER. V.

CHEMISTRY OF THE DINNER-TABLE.

WITH the chemical nature of *water*, and with some of its properties, the preceding chapters will have made my readers familiar. But it will not be superfluous to add something in this place to what has been already said.

Water, to be good for drinking, should possess the following qualities:—Bright and clear as crystal, when poured into a tumbler, it should sparkle with the gases rising through. Both oxygen and carbonic acid gas, which communicate to water its refreshing and thirst-quenching properties, should be present, and for this reason water should neither stand long in a warm room, nor in sun-light, nor be drawn long before wanted. It should possess no decided taste. Hard water contains a greater or lesser quantity of the salts of lime, more chiefly of sulphate of lime (gypsum) and of carbonate of lime (chalk held in solution by carbonic acid), which act injuriously upon some

constitutions. Water which has a flat taste, though far preferable to hard water, is not sufficiently refreshing, and hence an inordinate quantity must be imbibed for the purpose of quenching the thirst. Good water should but very slightly curdle soap, and should quickly form a lather with it. If a water can be obtained which cattle drink of readily, no hesitation need be felt about its quality.

Any person with a tendency to become stout, should restrict himself in the use of water, beer, and, unless his system has been impaired, of all intoxicating liquors. The moderate use of wines, or malt liquor, at dinner, is in nowise to be discouraged, except in the young. It must be a very exceptional case when the digestive organs of a *growing* person require a stimulus, and none such should indulge in even small quantities of fermented liquors, except under medical advice. I would only except from this rule the use of weak table-beer. It is impossible to specify the exact circumstances, under which it may be beneficial to take a moderate allowance of alcoholic stimulus, for the purpose of promoting either mental or bodily vigour. The Bible, in recommending wine as a gift of God, proves its capability of being put to legitimate uses. These uses are clearly legitimate, only so far as that they minister to health, energy, and virtue.

Alcohol acts directly on the lining of the stomach,

and its habitual employment *in excess* keeps this membrane in a state of irritation, amounting almost to inflammation: it destroys digestion and appetite, produces fœtid breath, and incapacitates from mental exertion, induces sloth, a deadening of the moral faculties, premature disease, and death.

Of the quantity of water contained in vegetables, fruits, and meat, few are well informed; and, as it would be impossible to speak of the *nutritive value* of the various kinds of food without taking into account the water they contain, I have drawn up the subjoined Table, showing the proportion contained in the fruits, vegetables, &c., most in use:—

	Per cent. of Water.
Common mushrooms contain . . .	96·00
Cabbages	92·00
Green-top turnips	90·00
Carrots	87·60
Beet-roots	} 87·00
Champignons	
Milk	
Kohlrabi	86·00
White Swede turnips	85·00
Pears	83·90
Currants	81·30
Peaches	80·20
Parsnips	79·40
Artichokes	79·20
Flesh	from 76·0 to 79·00

	Per cent. of Water.
Potatoes } contain	75·00
Yams }	
Cherries	74·90
Apricots	74·40
Greengages	71 00
Sweet potatoes	59·00
Kidney-beans	23·00
Haricots	16·00
Beans	14·50
Peas	13·00
Rice	12·50
Lentils	12·00
Wheaten-flour	10·00
Indian Corn or Maize	6·00

It will be noticed from the above, that flesh (corresponding in composition to the flesh of our bodies), contains 79 per cent. of water; and I think that the quantity of water drunk at the dinner-table should correspond as nearly as possible with this proportion. If our food be *dry*, the water drunk should be in quantity sufficient to bring the total amount up to 79 per cent.; if, on the contrary, water abound in our diet, then but little need be imbibed.

We have seen that the proportion of water in our kitchen vegetables bears some relation to the quantity contained in flesh; and that their value varies accordingly. The greater part of our vegetables have originally come from southern climates, chiefly

from Italy; and the number of them has increased prodigiously in the course of the last two centuries. The kitchen gardens of England were, until about the end of the sixteenth century, as scantily supplied with vegetables, as the pleasure grounds were with shrubs and flowers. "It was not," says Hume, "till the end of the reign of Henry VIII., that any salads, carrots, turnips, or other edible roots, were produced in England." The little of these vegetables that was used, was imported from Holland and Flanders, and Queen Catherine, when she wanted a salad, was obliged to despatch a messenger thither on purpose. The most important vegetable of the present day, the potato, was brought to England in 1586; but its culture for the next century must have been but partial, as the market price was 1s. per lb. Broccoli and cauliflower were introduced about the end of the sixteenth century from the Levant into Italy, and in the end of the seventeenth into England. The turnip was in cultivation in the sixteenth century; and it is stated, that when, in the years 1629 and 1630, there was a dearth in England, very good white bread was made of boiled turnips kneaded up with an equal quantity of wheaten flour.

The *fruits* used by our ancestors were neither numerous nor good. Gooseberries, strawberries, and currants, indifferently good apples and pears, and decidedly bad plums and cherries, were about all. It should be remembered too, that we owe

many of our fruits, now so familiar, to other countries, of which we have an intimation in some of their names.

Cherries were obtained from Cerasuntis, a city of Pontus, in Asia Minor. Lucullus, after the war with Mithridates, introduced them from Pontus into Italy; they were so pleasing as to be rapidly cultivated; and Pliny testifies that, twenty-six years afterwards, the cherry-tree passed over into Britain. The whole race of this tree was afterwards lost, and is said to have been restored by the gardener of Henry VIII., who brought it from Flanders. These facts may often be called to mind, for the cherry (*Prunus cerasus*, as botanists call it) is now one of our native trees, very common in woods; the wild fruit being well-flavored, though there is little pulp on the stone.

Another of our native wild trees is the *plum*, which has been so much improved by cultivation. There may be a doubt, indeed, whether the sloe is not the original stock, whence have been derived not only the several varieties of the plum, but even the peach, nectarine, and apricot. The *damson*, or damascene, was brought from Damascus.

The *strawberry* derives its name from the practice of gardeners laying straw under the plants as they came to maturity, to prevent the ripe berries from being soiled by the garden mould.

Black and red currants are natives of Britain; as

are also gooseberries. Cold as some of the countries of Northern Europe are, large and beautiful berries may often be obtained. Even in barren districts of Finland, and on the tops of Alpine mountains, where rocks appeared to be the only surface, cherries and gooseberries, with ruddy tints, have been met with. A traveller in Kamschatka found himself in a large forest, many of the trees being finely-grown, and amongst the underwood he perceived some bushes of large red berries, which, to his great astonishment, he discovered to be red currants, of a very large size and high flavor, but possessing a much more acid taste than those of our gardens.

With the *vine* mankind has long been familiar. Ripe grapes are among the most palatable, wholesome, and nutritious of all fruits. The weight of grapes which every vine can properly produce is proportioned to the thickness of the stem immediately above ground. At Hampton Court there is a vine which yields about fourteen hundred weight of very fine grapes. The grapes produced in Palestine are very large. The famous bunch of Eshcol, required to be borne by two men, greatly surprised and pleased the Israelites, when they first beheld, in a barren and sandy desert, the fruits which grew in the land they were to occupy. Even now, in the present neglected state of the country, some are still found to weigh twelve pounds.

The *pear* grows wild in our woods and copses, but it there yields fruit of a very inferior description, and very unlike the juicy produce of the orchard. From a deficiency of acid, this fruit is less wholesome for delicate stomachs than the apple; but to those of robust health it is both nutritious and excellent.

The *apple-tree* too is a native of Britain, being far from uncommon in woods and hedges, though the wild apples, or crabs, are small, dry, sour and unpalatable, and would not be much improved by culture. By sowing and re-sowing the seed, and crossing and re-crossing the sorts thence produced, the thousand known varieties of apples are procured. The apple is both wholesome and nutritious. Heat, when applied in roasting, baking, or boiling, tends to break down the interstices of the cells of the apple, to diffuse the acid and the sugar more uniformly through the mass, to dissipate water, and to render the whole more easy of digestion.

A most important ingredient of all vegetables, of unripe fruit, of the crust of pie and pudding, and of bread, is STARCH, known also to chemists under the various names of *amylum*, *fecula*, *amiline*, *amidine*. It is contained in the cells of vegetables, in the form of small white granules, which have no crystalline structure. These globules vary much in size and form, so much so indeed, that in the differ-

ent species of vegetables they may be distinguished by a practised eye. A character, however, which is common to the majority of *feculæ* (for thus are the granules technically distinguished), is a roundness of contour, when their particles have not been compressed by their contact in contiguous cells. Microscopical as well as chemical researches show that starch is homogeneous (from *ὁμῶς*, homos, like, and *γένος*, genos, kind) in properties as in composition; and that its globules are composed of concentric layers, the external layers of which have exactly the same character as the internal. At page 79, among other properties of starch, its atomic constitution has been already noticed. In its greatest state of purity it may be said to consist of—

Carbon	44·9
Hydrogen	6·3
Oxygen	48·8
	<hr/>
	100·0

Starch retains water with considerable force: the quantity retained varying with the temperature at which the drying is accomplished. Thus, the starch in potatoes, which is moist and porous, even when subject to strong pressure, still retains 45 per cent. of water. That of the shops contains 18 per cent.

Plants vary much, as to the quantity of starch contained in them, their bulbs and their seed. Thus we find in—

	Per cent. of Starch.
Rice flour	85
Maize	71
Wheat flour	from 39 to 77
Peas	47
Haricots	41
Lentils	40
Potatoes	from 12 to 23
Parsnips	6

It is not difficult to understand why potatoes and rice should increase in bulk when boiled, when we reflect that the starch granules, in boiling, swell to about thirty times their original size.

Several varieties of starch are employed for making puddings, and other light dishes.

In the Moluccas and Philippine Islands, grows a description of palm which yields a form of starch. When the pith of this palm is washed with water upon a fine sieve, a white powder is deposited by the milky liquid which passes through. This powder, when collected, forced through a metal sieve to granulate or corn it, and dried by agitation over a fire, forms the genuine SAGO of commerce.

ARROW-ROOT, which derives its name from the root of the *Maranta arundinacea*, owing to its supposed efficacy in counteracting the effects of wounds caused by poisoned arrows, is extracted, by a mechanical process, from the roots, when about ten or twelve months old. In Bermuda the roots are first

deprived of their paper-like scales, and then rasped by a kind of wheel-rasp.

The pulp is thrown into clean water, and stirred about to separate the fibrous parts, which are collected in the hand. The milky liquor which remains is poured through a sieve, and afterwards allowed to settle for some time. The arrow-root sinks to the bottom, and when the water is poured off, the white pasty mass that remains is placed on clean white cloths in the sun to dry. It is then fit for use. The process varies in Jamaica and at St. Vincent, but not materially. When pure, it has a dull and opaque-white colour, and crackles when pressed between the fingers. There are various kinds of spurious arrow-root in the market; many of the so-called "genuine" kinds are made from, or largely adulterated with, potato, and, although not unwholesome, are not nearly as nutritious as real arrow-root.

The *Manihot utilissima*, which is found in South America, has very large roots, rich in starch, from which TAPIOCA and CASSAVA are obtained. Tapioca differs from cassava only in being a purer kind of starch: the latter, however, is the more nutritious.

Among the Indians the cassava supplies the place of bread. The roots are scraped on a sort of rasp formed of small fragments of flint stuck into a plank; the pulp is put to drain in a long strainer made of the entire bark of a species of fig; the juice having

drained away, water is added to finish the washing; the liquid comes out nearly clear, and without bringing away any perceptible quantity of starch. To form the pulp into cakes of cassava, it is spread out on an earthen dish placed over the fire; the process being complete when the cassava is dry and slightly toasted on the outside. Cassava bread is not very palatable, but is frequently an indispensable article of provision with the South American traveller.

Arrow-root, sago, tapioca, and cassava, all contain a substance besides starch, which, although in amount it never rises above $3\frac{1}{2}$ per cent., is highly important. I allude to *albumen*, which has already been described at pp. 85 and 86 of this work. Starch, important as it is, would be a very unprofitable kind of food, were it not always associated with albumen, or a similar nitrogenized substance, which subserves the same purpose. By the process of boiling, the starch-granules become simply, though greatly expanded: arrow-root, for instance, in boiling water, quickly loses its whiteness and opacity, becomes transparent, and the whole of the water seems converted into a thick jelly-like mass. In the baking of a sago or tapioca pudding, there is no doubt that a portion of the starch becomes converted into *dextrine*, as in the case of bread-baking. This substance, when pure, has the same specific gravity as starch, viz., 1.51. It has also the same composition, for we find in 100 parts of dextrine:—

Carbon	44·3
Hydrogen	6·0
Oxygen	49·7
	<hr/>
	100·0

Owing to its solubility in water, dextrine is used in the arts as a substitute for gum; and it is this very solubility which renders cooked food containing originally much starch more digestible, as well as palatable.

The use of milk instead of water in provisions where starch abounds, tends to render them more tasty as well as more nutritious.

Some vegetables—as, for instance, turnips and carrots—contain no starch, but a principle not unlike it. It is well-known that the juice of all fruits contains a gelatinous substance to which many of them owe the property of forming jellies. This matter may be obtained by means of alcohol. If into a quantity of currant-juice lately expressed, a portion of alcohol be poured, a gelatinous precipitate is formed after a certain time; this jelly subjected to increasing pressure, and washed with dilute alcohol, gives the gelatinous principle in a pure state: this is PECTINE. It resembles isinglass. Thrown into about one hundred times its weight of water, it swells considerably, and at length dissolves completely, giving rise to a stiff jelly.

Pure pectine is tasteless, and does not affect the colour of blue litmus. Potash or soda does not

change it obviously; nevertheless, it is singularly modified under their influence, being changed into a peculiar body, having acid properties. PECTIC ACID has been found in every plant in which it has been sought for. It is contained in apples, pears, plums, cucumbers, &c.; in turnips and carrots, pectic acid amounts respectively to 2 and 5 per cent.

The composition of pectine and pectic acid is as follows:

	Pectine.	Pectic Acid.
Carbon	42·9	42·8
Hydrogen	5·1	5·2
Oxygen	52·0	52·0
	<hr/>	<hr/>
	100·0	100·0

From this it will be seen that the elementary composition of both is identical.

Sugar, too, is to be found in almost every part of vegetables. It is less abundant, however, in seeds, than in any other part. On account of its solubility in water, vegetables containing much of it, such as potatoes, turnips, and carrots, should be steamed rather than boiled. Both cane-sugar and grape-sugar have been met with mixed in vegetables. It has been already pointed out how starch and cane-sugar may be converted into grape-sugar or glucose, but the inverse has not, *as yet*, been accomplished. At no distant period, we may hope to see factories

established in England for the preparation from potato-starch, of a cane-sugar which shall rival the best produce of the West Indies.

To the same class of ternary compounds, found in vegetables—that is to say, of such as consist of the three elements, carbon, hydrogen, and oxygen, to which starch, sugar, pectine, pectic acid, gum, and oil, belong—must be added *woody fibre* and *cellular tissue*. Woody fibre consists, in fact, of two substances: one, the cellular substance, constituting the tissue of wood, and of all the organs of plants; the other, the woody substance properly so called, filling, and in some sort consolidating, the cells. Cellular tissue is identical in composition with starch. Thus:—

	STARCH.	CELLULAR TISSUE OF	
		Apple.	Mushroom.
Carbon . . .	44·9	44·7	44·5
Hydrogen . .	6·3	6·1	6·7
Oxygen . . .	48·8	49·2	48·8
	<hr/> 100·0	<hr/> 100·0	<hr/> 100·0

Now, the composition of woody fibre differs considerably from that of cellular tissue; it is richer in carbon. The elementary composition is:

Carbon	53·8
Hydrogen	6·0
Oxygen	40·2
	<hr/> 100·0

In the general acceptation of the term, the name of *wood* is applied to the solid part of the trunk and branches. It is heavier than water, and if it floats in this fluid, it is only because of the air with which its pores are filled. The composition of woody matter may be represented by carbon and water; of carbon the mean may be stated as 52, of hydrogen and oxygen, in the *proportions* which form water, at 48.

The stringy substance in the stalks of cabbages, of old turnips, in kidney-beans, &c., contains it.

We now understand better than formerly the changes which the cells of vegetables experience as they grow, and become old. It is by the appearance of the encrusting woody matter that their thin, transparent, and at first colourless walls, thicken, become opaque, and acquire strength. It need scarcely be said that the production of insoluble, indigestible woody fibre, does not add to the value of an esculent, but rather detracts from it; besides the actual discomfort in eating a tough vegetable, its nutritive value is greatly reduced by old age.

In the series of bodies now considered, one only possesses the property of crystallizing, viz., sugar. But among ternary compounds met with in vegetables, but more especially in fruits, must be classed certain *acids*, most of which assume regular crystalline forms. Vegetable acids present all the general characters of mineral acids. Thus—they redden blue

litmus paper, and form salts with metallic oxides. With potash, soda, and ammonia, they form salts soluble in water. These acids, free or uncombined, are very frequently met with in fruit, sometimes in the leaves; more rarely in seeds and roots; but in combination with bases (oxides) they are met with in almost all parts of plants. They are very numerous; but I shall confine myself to a few of the most extensively distributed of these acids.

Oxalic acid exists free in the hairs of the chick-pea. But it is met with more especially in combination with potash and lime. The *binoxalate of potash*, a compound of two equivalents of oxalic acid with one of potash, is sometimes called salt of sorrel, from its occurrence in that plant. It is also found in the wood-sorrel (*oxalis acetosella*), and in garden rhubarb, associated with malic acid. The crystals have a very sour taste.

Oxalic acid separates from a hot solution in colorless, transparent crystals. It tastes strongly acid, and is a deadly poison. (The proper antidote is chalk, or magnesia.) When heated in strong sulphuric acid, it is entirely decomposed into water, carbonic acid, and carbonic oxide. The hydrated oxalic acid may indeed be said to consist of—

1 equivalent of water HO

1 equivalent of carbonic acid . . CO²

1 equivalent of carbonic oxide . CO

The formula of the hydrate is C² O³ + HO; its

symbol is \bar{O} , the horizontal line placed over the initial letter indicating an organic acid.

Tartaric acid is always found naturally in combination with potash or lime. The grape, the tamarind, and the pine-apple contain *bi-tartrate of potash*. Along with other acids it is also present in the mulberry.

When new wine is set aside in casks, it gradually deposits a hard crust of *tartar*. This substance, when purified, forms the cream of tartar of the shops. It is soluble in 60 parts of cold water, but not in alcohol; hence, as the latter forms in the wine, bi-tartrate of potash separates.

The tartaric acid of commerce is wholly prepared from this acid salt; its principal employment being in certain processes of the calico-printers. The pure acid forms colorless, transparent crystals of large size, which possess an agreeable acid taste. It dissolves readily in water, and causes a violent effervescence when mixed with a solution of carbonate of potash or of soda; hence it is extensively used in artificial effervescing draughts. The formula of crystallized tartaric acid is $C^8 H^4 O^{10} + 2 HO$; its symbol is \bar{T} .

Citric acid gives sourness to the lemon, the lime, the orange, the cranberry, and the red whortle-berry. Mixed with much malic acid, it is found in currants, cherries, gooseberries, raspberries, strawberries, and the common whortleberry. It forms transparent,

colorless crystals, possessed of an agreeable acid taste; effervesces like tartaric acid with carbonate of soda, and like it, being without injurious action upon the system, is much employed for effervescing draughts. The formula of citric acid is $C^3 H^5 O^{11} + 3 HO$; its symbol is \bar{C} . The citron has lent its name to the acid.

In combination with lime, citric acid exists in the tubers, and with potash in the roots of the Jerusalem artichoke.

Malic acid is the acid of apples, pears, and various other fruits. Along with citric acid it occurs in many fruits. It is found abundantly in unripe apples, hence its name, from *prunus malus*, the botanical name of the apple tree. It is, moreover, the chief cause of the sour taste of the plum, the sloe, the elderberry, the barberry, the fruit of the mountain-ash, and rhubarb.

Malic acid is a crystalline solid, very soluble in water. It has an agreeable sour taste; becomes mouldy, and spoils by keeping. The formula of malic acid is $C^3 H^4 O^8 + 2 HO$; its symbol is \bar{M} .

Let us now turn to *quaternary* compounds, to those containing nitrogen, in addition to carbon, oxygen, and hydrogen, which are found in the various vegetables and other articles of food. Unless an esculent contain nitrogen, it cannot be said to be nutritious. In treating of bread, I have before alluded to this fact in page 81. The quaternary compounds *albumen*, *gluten*, *fibrine*, and *caseine*

already described, are as much constituents of vegetables as of animals. To these must be added *legumine*, a substance not previously mentioned. It abounds in many seeds used as vegetables, especially in such as are included in the natural family, *leguminosæ*, to which peas and beans belong.

Legumine is very soluble in cold water, and has a lustrous white appearance. On boiling a solution of it in water, it coagulates and falls in flakes like white of egg. The solidity of almonds, hazel-nuts, of the kernels of stone-fruit, of peas, lentils, and beans, is due to its presence. Analysis indicates a very great similarity in composition between legumine, and the four other quaternary compounds separable from wheat-flour. The following shows the composition of them:—

	Carbon.	Hydrogen.	Nitrogen.	Oxygen.
Legumine . .	50·5	6·9	18·2	24·4
Fibrine . .	53·2	7·0	16·4	23·4
Albumen . .	53·7	7·1	15·7	20·5
Caseine . .	53·5	7·1	16·0	23·4
Gluten . .	53·3	7·2	15·9	23·6

These nitrogenized substances, differing but little from one another, are those which are now recognised as distributed through the whole body of every vegetable. They all contain small quantities of *phosphorus* and *sulphur*; these are included in the above analyses, under the head of oxygen. Now, as the value of esculents must in some measure depend upon

the presence of one or more of these compounds, I subjoin similar information on this head to what has been already given with reference to the quantity of water and starch found in them. The per-centage value of grains, seeds, roots, and vegetables, as regards the quantity of nitrogenized or nutritive constituents, is as follows:—

Nutritive constituents.			
Wheaten Flour contains from 10 to 35 per cent.			
Dried Peas	contain	. . .	29 „
Kidney Beans	„	from 24 to 28	„
Green Peas	„	. . .	24 „
Lentils	„	. . .	22 „
Haricots	„	. . .	22 „
Maize	„	. . .	12 „
Rice	„	. . .	7 „
Yams	„	. . .	3 „
Mushrooms	„	. . .	2·9 „
Red turnips	„	. . .	2·8 „
Sweet potato	„	. . .	2·6 „
Cabbages	„	. . .	2·5 „
Parsnips	„	. . .	2·1 „
Beetroots	„	. . .	2 „
Potatoes	„	. . .	2 „
Kohlrabi	„	. . .	1·5 „
Turnips	„	. . .	1·5 „
Carrots	„	. . .	1·5 „

It must not be supposed, from the observation made in the last page, that *phosphorus* and *sulphur*

are contained in considerable quantities in these nitrogenized constituents. They are indeed included under the head of oxygen, but amount to little more than one per cent. More accurately stated than hitherto, the chemical composition of albumen is as follows:—

Carbon	54·84
Hydrogen	7·09
Nitrogen	15·83
Oxygen	21·23
Phosphorus	0·33
Sulphur	0·68
	<hr/>
	100·00

The existence of sulphur in white of egg is easily shown; a boiled egg blackens a silver spoon.

Sulphur is an element of great importance. Sicily furnishes a large proportion of it for European consumption. When pure, it is a pale yellow, brittle solid. Its specific gravity is 1·98. It melts when heated, and distils over unaltered, if air be excluded. Sulphur or brimstone is largely used in the manufacture of sulphuric acid (oil of vitriol) and of lucifer-matches. In its chemical relations, it bears great resemblance to oxygen. Its combining proportion or equivalent is 16: its symbol S.

The *phosphorus* of albumen is obtained by plants from the soil. Not that it is ever contained in the latter in an uncombined form, but in chemical com-

bination with oxygen and lime, as phosphate of lime or bone-earth. This phosphate passes into the organism of plants, and ultimately into the bodies of human beings or animals, to which these latter serve for food. By a chemical decomposition, the nature of which it is not easy to explain, the more highly organized parts of plants extract their phosphorus.

This element is always obtained from burnt bones. When pure, phosphorus very much resembles wax, and is soft and flexible. Its specific gravity is 1.77. It melts at the low temperature of 108° , and boils at 550° . Its combining proportion or equivalent is 16, the same as that of sulphur. It is not soluble in water, and is usually kept immersed in that liquid on account of its easy inflammability. It sometimes takes fire by the heat of the hand, and demands great care in its management; a blow or hard rub will kindle it. A stick of phosphorus held in the air always appears to emit a whitish smoke, which in the dark is luminous. To this property it owes its name, $\phi\omega\sigma\phi\acute{o}\rho\omicron\varsigma$, phosphoros (from $\phi\omega\varsigma$, phos, light, and $\phi\epsilon\rho\epsilon\iota\nu$, pherein, to carry). The luminous appearance of the sea at night, when disturbed by a ship moving through it, is owing to the presence of myriads of small marine animals, of various kinds, which possess the power of emitting the peculiar light, called, from its supposed origin, phosphorescent. The light of the glow-worm, the lantern-fly, and other insects, is attributed to the same cause;

and every one knows that most fish, and molluscous animals, such as crabs and lobsters, when in a state approaching to, or of actual decomposition, give out the same kind of light.

The spontaneous inflammability of Will'-o-the-wisp is due to a combination of phosphorus with hydrogen.

The consumption of phosphorus for the apparently trifling article of lucifer-matches, is something prodigious.

When phosphorus is set on fire in the air, it burns with a bright flame, generating a snow-like, caustic vapour. This is *phosphoric acid*, formed by the union of phosphorus with the oxygen of the air. It is composed of one equivalent of phosphorus with five of oxygen. As the symbol of phosphorus is P, so that of phosphoric acid is PO^5 .

Phosphoric acid has great affinity for water, with which it combines, forming three distinct compounds. It is a very powerful acid; its solution in water has an intensely sour taste, and reddens litmus paper. Indeed there are few bodies that present a greater degree of interest than this substance.

But to return more immediately to our subject. The food of man, as regards vegetables, always contains nitrogen, in one or more of the five forms—albumen, gluten, fibrine, caseine, and legumine. The nutritive properties in food increase in the precise ratio of the presence of these substances; or, in

other words, the value of different kinds of food is in proportion to the quantity of *nitrogen* or *azote* contained in them. The experiments of Magendie have shown that substances, such as sugar and starch, which contain no azote, will not support life; and, on the other hand, it is ascertained that the quality of flour, for example, improves as the amount of gluten which it contains increases. We must therefore conclude, that the nutritious principles of plants and their products reside in their azotized principles. Not that these azotized principles alone are sufficient for the nourishment of animal life: for it is found that every highly nitrogenized vegetable is generally accompanied by starch, gum, bone-earth, and other matters which concur in nutrition.

Men and animals, then, find the several substances which make up their bodies ready formed in the food they consume. A *vegetable* may be defined to be an organized being, which derives its food from gases and the soil; while an *animal* exists by incorporating into itself, from foreign sources, matter similar to that of which its own substance is composed. The constituents of *meat* are, as far as regards their nutritive properties, very similar to those of vegetables. Animal fibrine, albumen, and caseine, have their counterparts in vegetables: the history of animal albumen is that of vegetable albumen.

As food from without can only be made available by being first converted into *blood*, and as it is the material from which all the secretions are derived, I shall proceed shortly to describe it. The blood in all vertebrated animals has a red color, and a temperature above that of the medium in which the creature lives. In the ordinary state the blood has a slimy feel, a density of 1.053, and a decidedly alkaline reaction, from the presence of an alkaline phosphate of soda. To the naked eye, blood, like milk, appears a homogeneous fluid; but it is not so in reality. When examined by a good microscope, it is seen to consist of a transparent, pale straw-colored liquid, in which countless little red discs float. This may be readily seen when blood is left to itself, for it then coagulates, and separates into two distinct parts.

The *serum* of blood is the clear pale fluid part, and may be said to be an alkaline solution of albumen in salt water.

The *clot* or *crassamentum* is a mechanical mixture of *fibrine* and the *coloring principle*, swollen and distended with *serum*. In the blood we have an instance of fibrine in a soluble state. Its character may be best studied by agitating fresh-drawn blood with a bundle of twigs, when the fibrine attaches itself to the latter in form of long, white, elastic threads or fibres, which, under the microscope, appear to consist of small globules ar-

ranged in strings. It is quite tasteless, and insoluble in both hot and cold water. The colour of the clot is owing to a compound called *hæmatosine*, which has many properties in common with albumen; but the globules of the blood, in which the color naturally resides, are not composed of hæmatosine alone, but contain another albuminous compound, to which the name of *globuline* has been given.

If blood is evaporated to dryness, and exposed for some time to a red-heat in the air, it will burn away, with the exception of a small amount of *ashes*. These consist of alkaline phosphate of soda, phosphates of lime and magnesia, phosphate of iron, common salt, and sulphates of potash and soda; of the same constituents, in fact, which we find in the ashes of our principal articles of food (eggs, milk, bread and meat, &c). In vegetables we find these ashes most abundant, according to their power of supporting nutrition. Thus, they abound in the seeds of our corn and leguminous plants; for example, in wheat and in peas.

Muscular tissue, muscular fibre, or meat, is composed chiefly of fibrine; mixed, however, in the ordinary state, with blood, membranes, nerves, fat, &c. &c. A thin slice of lean meat, washed in cold water until perfectly white, affords an excellent example of fibrine in its insoluble form. Now, the basis of all meats, whether fish, flesh, or fowl, is

the same. If we make an extract of finely minced meat with water, we obtain a reddish-colored fluid, having the taste peculiar to the blood of the different classes of animals. If we heat it, albumen coagulates at a temperature of 150°, while the color remains; but if the heat be continued, the fibrine, together with the coloring matters and cellular tissue, separates, and a clear liquid is obtained. This *broth* will be found to be distinctly acid. The acidity of the juice of flesh depends upon the presence of free lactic and phosphoric acids. If one or other of these acids were removed, meat would be found to possess an alkaline reaction, for the blood has always such; indeed, all the conditions of an electrical current are present in the living organism. The blood-vessels and lymphatics contain an alkaline fluid, while the surrounding fluid (that of the flesh) is acid; the tissues of which the vessels are composed being permeable for one or other of these fluids. It is, therefore, very probable, says Liebig, that an electrical current takes a share in the vital processes, though very little is known about it.

The chemistry of flesh demonstrates that, according to the duration of boiling, more or less complete separation of its soluble constituents takes place. As flesh taken as food is again to become flesh in the body, it should, as far as possible, contain all the original constituents of the raw meat. The

bouilli without the *bouillon* is so much the less adapted for nutrition, as the quantity of water in which it has been boiled is greater; if meat be extracted with cold water, all the sapid and odorous principles are, together with the albumen, transferred to it. The smell and taste of *roast* meat arise from the soluble constituents of the juice, which have undergone a slight change under the influence of a higher temperature. Meat which has been rendered quite tasteless by boiling with water, acquires the taste and peculiarities of roasted flesh, when moistened and warmed with a cold water infusion of raw meat which has been evaporated till it has acquired a dark brown color. From all the different kinds of flesh we obtain, by the aid of cold water, the whole of the albumen present in them, in the soluble form. Muscular fibre is everywhere surrounded by a liquid containing it, and the *tenderness* of meat is dependent upon the quantity present. In young animals the quantity of albumen is great; in old ones it is small. Now, when meat is to be eaten, the albumen should be retained in it; for not only does it preserve the fibrine from becoming hard, but it gives to it softness and delicacy. The influence of boiling water upon albumen is well known.

The best method of boiling meat intended for food is to introduce it into *boiling water*; if the boiling be kept up for five minutes, and then so

much cold water added as to reduce the temperature to 165°, and the whole kept at this temperature for some hours, all the conditions are united which give the flesh the quality best adapted for its use as food. When it is introduced into the boiling water, the albumen immediately coagulates from the surface inwards, and in this state forms a crust, which no longer permits the external water to penetrate into the interior of the mass of flesh. But the temperature is gradually transmitted to the interior, and there effects the conversion of the raw flesh into the state of boiled. The flesh retains its juiciness, and is quite as agreeable to the taste as it can be made by roasting. When the temperature of the interior of a piece of meat has not reached 144°, it presents a blood-colored or *underdone* appearance.

The flesh of *poultry* is sooner done than meat, because it contains little blood, and therefore requires a lower temperature.

The use of *lard* in roasting is to prevent the extraction of the *tasty* constituents from the flesh by its juices, and the evaporation of the water, which causes hardening.

Now, although the introduction of the raw meat into boiling water is the best process for *dressing* it, it is the worst for obtaining *soup*. If the raw meat be placed in *cold* water, and this brought very gradually to the boiling point, there occurs, from

the first moment, an interchange between the juices of the flesh and the external water. The flesh loses, while the soup gains in sapid principles, and extracts both lactic and phosphoric acids,—two most important constituents of the gastric juice.

The best method of preparing so-called *beef tea*, is to take finely-chopped raw beef, to mix it with its own weight of cold water, and, after the lapse of about three minutes, to heat it slowly to boiling. It should be allowed to boil for two or three minutes, and should then be strained through a cloth; when an equal weight of the most delicious and strong beef tea, (such as cannot be obtained by boiling for many hours,) is at once obtained. When properly seasoned, it forms the very best soup that can be made.

It has long been customary to ascribe to the gelatinous matter dissolved during boiling, which gives to concentrated soup the property of forming a jelly, the chief properties or peculiarities of the soup; but Liebig has shown this to be a mistaken notion. The simplest experiments prove that the amount of dissolved gelatine in well-prepared soup is so small, that it cannot come into calculation in explaining its nutritive properties. *Gelatine* (isinglass is pure, glue impure gelatine) is, in itself, quite tasteless, and consequently the taste of the soup cannot be derived from it. Boiling water, when allowed to act for five hours on finely-chopped

flesh, does not dissolve more than the fifth part of the matter soluble in cold water, even after the albumen has been separated by heating the cold infusion; and this fifth part, besides, does not consist of pure gelatine, but contains all the products dissolved out of the muscular fibre by long boiling.

It is equally customary to ascribe great strength to dark-coloured soups. A little burnt sugar (caramel) or burnt onion, will give depth of color to the beef-tea prepared after the above prescription.

Salted meat is deficient in nutritive and digestive properties, and should never be eaten by a dyspeptic person. In the process of salting flesh, the acids, much of the albumen, and other matters, are removed in the brine; and, as I have already pointed out that the juice of flesh is not very dissimilar to the gastric juice, it is obvious that its removal must render the meat less nutritious. It is probable, that if, before salting, the meat were plunged for three minutes into boiling water, it would not lose so much of its goodness. The practice of using salt meat at infirmaries is highly objectionable. The object—viz., that of making it keep in warm weather—may, I believe, be effected by plunging the fresh meat into slightly-salted boiling water; and re-heating till the water again boils.

Fully to explain the nature and uses of *common salt*, would occupy too much space; its importance will be clearly perceived in the record of the fact,

that more than one-half of the total weight of the ashes of blood consists of salt. It has become a necessity even for the rudest nations; in not a few countries it is the most valuable mercantile commodity. Of the various kinds of vegetable food, seeds contain the smallest amount of it; green vegetables the largest proportion. Such as consist most largely of starch, as potatoes and rice, require most salt to render them palatable. Moreover, when we consider that one of the constituents of salt (soda) is essential to the formation of bile, and that the free acid contained in the gastric juice is hydrochloric acid, and derived from salt;—all these facts, taken together, seem entitled to be considered as proofs of the necessity of the presence of salt for the vital process, and of the addition of salt to the food of men.

The earth, the sea, and spring-waters, abound in salt or *chloride of sodium*, as it is called. In some places it is found in the interior of the earth, in immense beds, from which it is broken up and dug out. It looks like a stone, and is therefore called *rock-salt*. In those places where the rock-salt is mixed with stones and earth, a hole is bored in the middle of the bed, and water is let into it. The water is pumped out again as soon as it has become saturated with the salt, and is again expelled by evaporation. In the so-called natural brine springs, salt is found in solution, and also obtained by eva-

poration. In hot countries, salt is also prepared from sea-water, which is evaporated in shallow tanks by the heat of the sun. It is called bay-salt, and has a bitterish taste, owing to the presence of salts of magnesia. A pound of sea-water contains about half an ounce of salt.

Salt crystallizes in cubes, and is as soluble in cold water as in hot. When thrown into the fire it *crackles* briskly. This proceeds from a trace of water which remains in the crevices of the crystals; on being heated, it expands, and bursts the crystals asunder.

Chloride of sodium or salt is a chemical compound of the two elements, *Chlorine* and *Sodium*. One of its constituents, chlorine, is the greatest bleaching agent we are acquainted with. It is a yellow gaseous body, of intolerably suffocating properties, producing very violent cough when inhaled to an exceedingly small extent. Its name is derived from the color of the gas; $\chi\lambda\omega\rho\sigma$, chloros, signifying yellowish green. Its specific gravity is 2.5; its equivalent 36. Symbol Cl.

Chlorine is one of the best and most powerful disinfecting agents, but its employment requires care.

Hydrochloric acid, a compound of one atom of hydrogen with one of chlorine, is, as has been already remarked, a constituent of the gastric juice. The liquid acid of commerce, or spirits of salt, is a solution of hydrochloric acid gas in water.

Sodium, the other component of salt, is a silver-white metal, lighter than water, and possessed of the remarkable property of burning with flame when thrown upon hot water. The latter is decomposed; its oxygen unites with the sodium, forming soda, whilst its hydrogen is set free. The equivalent of sodium is 24, and its symbol (Natrium) Na.

These two extraordinary substances in chemical combination form that most useful and abundant substance, common salt. Without it no complete digestion can take place. The deficiency in nutritive properties, which is the characteristic of salt meat, is then due,—not to the presence of an excess of salt, but to the fact that the salt has removed the juices of the flesh, which are so essential in digestion.

Nor are all kinds of flesh of equal value. Veal, for example, is totally different from beef, the inorganic parts or ashes of which latter are much richer in alkalies. It also contains more gelatine and less fat than beef. Further than this, it is essentially distinguished from beef, by its containing much less *iron*. Now, iron, in the state of oxide, is one of the chief constituents of the blood. A strong diet must contain a certain amount of iron; for it is quite certain that if excluded from the food, life cannot be supported.

Vegetable food, which includes, of course, bread,

contains as much iron as beef, or red meat generally. Veal contains only one-third of the iron that beef does.

Fish contains even less iron than veal; its other constituents are the same as those of beef. When fish is boiled, a part of the soluble ingredients is taken up in the soup, and the nutritive value diminished.

The advantage of *stewing* over boiling depends on the fact, that in the former process all the soluble matter is retained in the sauce or juice, which is served with the meat.*

Taste being the best test of good cookery, it is obviously of the highest importance, in the process of cooking, to retain, as far as possible, the sapid principles of vegetables, as well as of meats. The practice of boiling meat or vegetables with large quantities of water, which is thrown away, and with it the whole, or nearly the whole, of the soluble matter, is clearly objectionable. The process of *steaming* is, in most cases, far preferable to boiling. Potatoes should always be boiled in their skins, for these keep in much that is valuable. Baked or roasted potatoes are, however, most wholesome; and this is owing partly to the removal of water, and partly to the change which the starch undergoes.

* For further information, see Liebig on Food, from which work the information on flesh here given is taken.

We must not altogether overlook so important an element of dinner as *cheese*. It is a constituent of milk. When milk, freed from cream, is heated to 150°, or thereabout, and mixed with a little rennet, (an infusion of the stomach of the calf in water,) it coagulates, and gradually separates into a solid white matter, called *curd*, and a liquid portion, distinguished by the name of *whey*. Curd, when in a state of purity, is known by the name of *caseine*. It has many properties in common with albumen, and, like it, may be obtained in two states; namely, uncoagulated, when it is soluble, and coagulated, when it is insoluble in water. It is precipitated from its aqueous solution by acetic acid, which is not the case with albumen. It is coagulated by a boiling heat, but slowly: the scum we see on boiled milk is coagulated casein.

Cheese is coagulated casein,* subjected to pressure for the purpose of freeing it from the whey. But if cheese consisted of nothing but casein, it would be hard, horny, and utterly tasteless. Good cheese is, however, always made from milk still retaining its cream or butter; and in Stilton, which is one of the richest cheeses, the milk is not only allowed to retain its natural quantity of cream, but an additional quantity is added. The fresh cheese being kept constantly cool and dry, undergoes a

* Casein is frequently spelt without the final *e*, as are also words with a similar ending.

particular kind of putrefactive fermentation, (the details of which are very little understood), by which principles are generated which communicate to it a particular taste and odour.

Cheese, then, is a combination of—a highly nitrogenized substance, *caseine*, with *butter*. The difficult digestibility of cheese, as compared with meat, is no doubt owing to its composition. Not only is it insoluble in water, but it brings with it little that aids digestion. The use of a morsel of decaying cheese as a relish is no doubt an aid to digestion, for it acts as a solvent upon the food in the stomach; that is to say, in the same way as does a ferment.

In the third chapter of this work, I have alluded to Liebig's division of all classes of food into such as keep up the animal heat, and such as restore the waste of the flesh. There ought to be a definite relation between the amount of nitrogenous or nutritive matter taken into the system, and that of the starchy or calorifiant (heat-producing); hence a right *diet* must consist of that in which the nutritive matter is properly proportioned to the calorifiant matter.

By a due admixture, we can obtain a diet of a composition analogous to that of milk or of wheaten bread. By the addition of bacon or fat pork to peas and beans; of fat bacon to veal; of potatoes to beef, of rice to mutton; we increase in each case the proportions of heat-giving matter. The same result, though to a much smaller and less useful

extent, is obtained by the use of fermented liquors, which, when taken with lean flesh and little bread, yield a diet approaching to milk.

We know that when food is withheld, the body of man loses weight; that by the food, the weight of the body, and the power of producing new manifestations of force, is restored. In a state of rest, man requires less food than in that of active exercise. It is, therefore, not a matter of indifference what is the quality of the food which he must daily consume, in order to recover the original power, and to perform on the following day an amount of work equal to that of the previous one.

In a healthy adult, whose weight should not be perceptibly altered from year's end to year's end, the proportion of the parts and their composition are the same as at the beginning of the period. The whole quantity of the food taken in the course of the year has not been employed in increasing the weight of the body, but in repairing the waste produced by exertion. For every movement of the limbs, every glance of the eye, every thought that crosses the mind, is accompanied by the transformation of a certain amount of nitrogenous matter into a soluble form, to be ultimately expelled from the system.

To preserve the human system in a healthy condition, the quantity of food taken at meals should be in proportion to *age* and the amount of *exercise*

taken. A person who takes much active exercise in the open air, or whose work is such as to give vigorous employment to the muscles, will be able to eat double the quantity that would be good for one who leads a sedentary life. The state of the weather, too, has much to do with the quantity, for the colder it is, the more food is necessary. The Esquimaux will devour as much as twelve pounds of raw whale's blubber in a day; whilst the inhabitants of hot climates live on a very spare diet.

It should, therefore, be borne in mind, that we are not in all cases to eat a certain quantity of food merely from custom.

The food that is required, and hence the appetite, must be proportional to the amount of carbon required to supply the animal heat. Now, in hot climates, where the external cooling is less, less heat is required, the appetite is weaker, and the usual food, consisting of fruits and vegetables, contains a far smaller amount of carbon than in cold climates, where the appetite is keen, and the food highly carbonized, such as flesh, or even blubber. For the same reasons, warm clothing, by diminishing the loss of heat by external cooling, blunts the appetite; and those who remove from a cold to a warm climate always find that their appetite fails. This is a warning from nature to diminish the amount of food taken; and if it were attended to, and the common but absurd practice of stimulating the ap-

petite by ardent liquors, hot spices, and pickles, abandoned, Europeans might enjoy better health in the Indies than they usually do.

It is further very important to avoid *over-drinking* at meals; large draughts of water or beer chill and disorder the stomach, rendering it unfit to perform the functions of digestion. It should be remembered that the quenching of thirst does not depend upon the quantity of liquid imbibed; and that, in general, less than half a pint of fluid, whether it be in the form of water, beer, coffee, tea, or cocoa, drunk in small quantities at a time, will suffice at each meal.

QUESTIONS ON CHAPTER V.

Can you, from memory, give some idea of the nature of water, as given in previous chapters? For example—its composition, its properties when pure? What are the names of the salts usually abounding in spring water?

What are the qualifications of a good water? Is soap a test of its goodness?

Has the nutritive value of food any necessary connexion with the quantity of water contained in vegetables? How much water does milk contain? How much do we find in potatoes and meat? How much in the ordinary dessert fruits?

To what extent is the use of alcoholic liquors in the young allowable?

From what country have our chief vegetables been brought? When were carrots and turnips introduced? To what place did Queen Catherine send for a salad? In what year was the potatoe brought to England? Broccoli and cauliflowers, when were they first introduced?

What character did the fruits used by our ancestors bear? Are any of their names indicative of the countries from which they were brought? Give an instance. About what time was the cherry first cultivated in England? When was its cultivation restored? Does the cherry grow wild? What is the origin of the plum, and the supposed origin of the peach, nectarine, and apricot? From what country was the damson brought?

Whence does the strawberry derive its name?

Of what country are currants the natives? Have they been found in the North of Europe? Relate what you know?

Has the vine been long known? Is it a wholesome fruit? How many hundred-weight of grapes has the Hampton vine been known to bear? What do you know of the Eshcol grape?

Does the pear grow wild in England? Why is the pear a less wholesome fruit than the apple?

What country is the apple a native of? How have the varieties now known been obtained? How many varieties are there supposed to be? What effect has cooking upon the apple?

What is the most important ingredient of vegetables? Under what various names is the substance known? In what form is it contained in the cells of vegetables? Is it possible to distinguish the vegetable from the form of the starch granule? What is the word homogeneous derived from? What percentage of carbon does starch contain? Does it contain nitrogen? What, then, are its other constituents? Has it any great power of retaining water? Does the starch of the shops contain much? How much starch is contained in rice? How much in potatoes and peas?

Are any varieties of starch used in making puddings? Name them.

How is sago prepared? What kind of tree is it obtained from?

From what property does arrowroot derive its name? What is its botanical name? How is it prepared? What appearance

does it present when pure? With what root is it frequently adulterated?

What is the name of the plant from which tapioca is derived? In what respect does it differ from cassava? Relate the manner in which the Indians prepare cassava bread.

What substance do these various forms of starch contain? What do you know of its properties? Is it essential? What is its per centage in cassava? What change does arrowroot undergo in boiling? Into what new substance is starch changed when strongly heated? Does it differ from starch in composition? How does it differ in property?

What is the use of milk in cooking provisions in which starch abounds?

What is the name of the principle contained in turnips and carrots? To what principle is the jelly in fruits due? How may it be obtained from currants? What substance does pectine resemble? Is pectine contained in carrots? What is the name of it then? How much does it amount to in carrots and turnips? Does pectine differ much from starch in composition? Does it differ from pectic acid?

Is sugar found in vegetables? How should vegetables which contain much of it be cooked?

What does woody fibre consist of? Does cellular tissue differ from starch in composition? In what respect does woody fibre differ from cellular tissue?

How may wood be represented chemically? Is it contained in cabbage-stalks?

What changes do the cells of vegetables undergo, in growing old? Is woody fibre digestible?

Of the various substances in vegetables, consisting of C, H, and O, do any of them crystallize? Of what nature are the substances met with, more especially in fruits? What are their properties? Are they ever met with in vegetables?

Does oxalic acid ever exist in a free state? Does it usually so exist? In what plants more especially is it found in a state of combination? What is the name of the salt? What appearance does the pure acid present? What are its pro-

perties? What is the best antidote to counteract its poisonous properties? What is its composition? Write down its formula from memory? How is an organic acid briefly signified?

Is tartaric acid ever found in a free state? From what salt is it always derived? Whence is that salt obtained? What is the common name of the salt? Is it very soluble in water? Why does it separate from wine? For what chief purpose is tartaric acid employed? Has it any other use? What is its chemical composition?

What fruits does citric acid abound in? Whence its name? What are its most prominent properties? What is it chemically composed of? Is it ever found in the artichoke? In what part? As what?

What is the name of the acid of apples? What other fruits does it occur in? Whence its name? What is it composed of?

What are quaternary compounds? What are the names of the chief quaternary compounds in vegetables? In what plants does legumine abound? What are its chief properties? To what is the solidity of the kernel of the almond owing?

How much nitrogenized matter is contained in wheaten flour? How much in green peas? Is there more in rice than potatoes? Which vegetable contains least?

What elements, besides C, N, H and O, are to be met with in albumen? Is the quantity of sulphur and phosphorus great?

How can the presence of sulphur in white of egg be proved?

What country furnishes the chief supplies of sulphur? What is its specific gravity? What effect has heat upon it? What is its common name? What purposes in the arts does it subserve? What element does it resemble in its chemical relations?

From whence is the phosphorus of the albumen of vegetables obtained? Is it ever contained in the soil in an un-

combined form? What is the name of the salt which more especially abounds? Whence do animals obtain phosphorus or its compounds? From what source is phosphorus obtained? What is its appearance? Its specific gravity? What is its combining proportion? How is it preserved? Why so? Is it dangerous to handle? What is its name derived from? To what is the phosphorescence of the glow-worm supposed to be owing?

What compound of phosphorus is supposed to give to Will-o'-the-wisp the power of self-inflammability?

Is phosphorus at all used in manufactures?

When phosphorus burns in air, what compound is formed? What is phosphoric acid composed of? Has it any affinity for water?

What are the names of the five nitrogenized constituents of vegetable food? Upon the presence of what substances does the value of food depend? Does the quality of flour vary at all? Why may we conclude that the nitrogenized parts of plants are not alone suitable as food?

How would you define a vegetable? In what respect does an animal differ? Do the constituents of meat differ much from those of vegetables?

What color is the blood of vertebrated animals? What temperature has it usually? In what respect is blood like milk? What is the cause of the alkalinity of blood?

What is the name of the clear liquid part of blood?

What is the clot? By what other name is it known? Is fibrine contained in the blood? How may it be obtained? What is its character? What is the word hæmatosine derived from? State what you know of its nature? What is the name of the other component of the globules of blood?

What do we mean by the ashes of blood? How are they prepared? What do they consist of? Do we find them in vegetables? In which do they most abound?

What is meat chiefly composed of? What is it mixed up with? What affords a good illustration of fibrine? Is the basis of fish and fowl the same? Is broth acid? To what

acids do we ascribe the cause? Is meat alkaline or acid? What part does Liebig suppose the acids and alkalies of the body to perform?

To what is the smell of roast meat attributable? To what substance more especially is the tenderness of roast meat due? What influence does hot water exercise upon albumen? Of what elements does albumen consist?

How should boiled meat be cooked? What is the theory of it? What is the temperature of under-done meat?

Why is poultry sooner done than meat?

What is the use of lard in roasting?

How should soup be made? What is Liebig's prescription for beef-tea?

What is gelatine? Has it anything to do with the strength of soup?

Has the color of soup anything to do with its strength? How may color be given? Do you remember the chemical name of burnt sugar?

Why is salt meat deficient in nutriment?

What is the use of common salt? How much is contained in blood? Is it ever a matter of commerce? What vegetables contain most salt? What least? What arguments may be used for the necessity of salt?

What is the technical name of salt? What is rock-salt? Why so called? How is salt obtained from natural brine-springs? What is bay-salt? What gives it its bitter taste? How much salt does sea-water contain?

In what form does salt crystallize? Why does it crackle in the fire?

What two elements does salt consist of? What is chlorine used for? What color is it? What is its name derived from? Is it dangerous to breathe? What is its specific gravity? Its equivalent? Its symbol?

What is hydrochloric acid? What is it composed of? In what part of the body is it found? What is its common name?

What is sodium? What are its properties?

Is common salt the cause of the less digestibility of salt meat?

Are all kinds of flesh of equal value? How is beef distinguished from veal?

Is iron contained in the blood? Is it a necessary constituent of food?

Does vegetable food contain iron?

Does fish differ from beef or veal? Does it suffer loss in boiling?

What is the advantage of stewing over boiling?

Why is the practice of boiling meat or vegetables with much water objectionable? Which are most wholesome, baked or boiled potatoes? Why?

In what liquid is cheese found? What is the chemical name of curd? What is whey? How is it obtained? What are the properties of casein?

What, then, is cheese? Does it consist of pure casein? How is Stilton made? Is it very digestible? Why not?

Into what two classes may all kinds of food be divided? Of what should a right diet consist? Can we obtain a right diet by due admixture?

What is the object of food?

In what climate is the appetite greatest? Why? Should the same amount of food be eaten at all times? Why not? Why does a removal from a cold to a warm climate diminish the appetite?

Why should over-drinking be avoided? What may be considered a fair average amount of drink of any kind?

CHAPTER VI.

THE CHEMISTRY OF GLASS, CHINA, AND EARTHENWARE.

OF the many beautiful discoveries effected by the ingenuity of man, none is so beautiful, so perfect, in fact so nearly approaching to the productions of nature, as GLASS. When, or by whom, the art of glass-making was discovered, is unknown; but that it was practised in very ancient times is certain. A kiln of bricks could scarcely be burnt, or a batch of pottery made, but some of the bricks or ware would be, at least superficially, turned to glass. From many writings of the ancients, it is certain that glass was well known to them.

The glass-works of Sidon and Alexandria enjoyed considerable reputation in the time of Pliny. From thence, at one time, Rome was supplied. It is asserted that Nero paid no less than £50,000 for two glass cups with handles, not remarkable for their size, but valuable for their transparency. But

it was not until long after the time of Nero that the Roman artisans became proficient in the art of glass-making. One of the most celebrated specimens of ancient art, is the Portland Vase in the British Museum. It was found about three centuries ago, enclosed in a marble sarcophagus, in the tomb of Alexander Severus, who died in the year 235. The body of the vase is deep blue glass, and is ornamented with delicate white opaque figures in low relief, in the style of cameos.

In the thirteenth century, the manufacture of glass was successfully prosecuted on an extensive scale at Venice, where it was probably introduced by the crusaders, who had contrived to learn the glass-making processes of the Phœnicians during the Holy War. The quality of the drinking-glasses and mirrors manufactured at Venice has been highly extolled, and the artisans of that city continued to supply the greater part of the glass vessels required for all Europe, during two or three centuries.

France was the European state in which the manufacture of glass was next conducted on a considerable scale, the Venetian processes having been introduced there, during the ministry of M. Colbert, by some French artists who had resided in Venice.

The manufacture of glass was not prosecuted on an extensive scale in England, until the middle of the sixteenth century; but it is believed that small

glass articles have been made at a very early period, the processes being derived, most probably, from the Phœnicians, when trading to our country for tin. The glass rings termed the *glain neidyr*, or Druid glass rings, which are frequently found near Aberfrau Palace, are supposed to have been made by the Druids. Window-glass was commenced in 1557, at Crutched Friars, London; and a flint-glass manufactory was established shortly afterwards at Savoy House, in the Strand. Very little progress was made until 1670, when the processes practised at Venice were introduced here by some artisans from that country, under the patronage of the second Duke of Buckingham.

This brief sketch of the progress of the glass-manufacture, which I have taken almost *verbatim* from Parnell's excellent treatise on Applied Chemistry, I conclude by the following paragraph from the writings of one of the most celebrated authors of the last century :—

“ By some fortuitous liquefaction was mankind taught to procure a body at once in a high degree solid and transparent, which might admit the light of the sun and exclude the violence of the wind; which might extend the sight of the philosopher to new ranges of existence, and charm him, at one time with the unbounded extent of the material creation, and at another with the endless subordination of animal life; and, what is yet of more im-

portance, might supply the decays of nature, and succour old age with subsidiary sight. Thus was the first artificer in glass employed, though without his own knowledge or expectation. He was facilitating and prolonging the enjoyments of light, enlarging the avenues of science, and conferring the highest and most lasting pleasures; he was enabling the student to contemplate nature, and the beauty to behold herself."

Glass, as is well known, is an artificial product. As a natural product, resembling glass in many of its best properties, we recognize quartz, or rock-crystal; and this mineral, often perfectly transparent and colorless, is so hard as to give sparks when struck with a steel, and is infusible in fire. The fine crystals are cut into ornaments, and frequently used as a substitute for glass in spectacles; they are then called pebbles, and possess one advantage over glass, in not being easily scratched. *Brown* and *yellow rock-crystal* are found in great beauty in the mountain of Cairngorm, in Scotland. That beautiful gem called *Opal*, is a specimen of pure rock-crystal, combined chemically with water. In fact, all the varieties of beautiful stones, known and valued by young and old, under the various names, *Agate*, *Bloodstone*, *Carnelian*, *Flint*, *Amethyst*, and *Onyx*, are but varieties of melted *sand*, colored by metallic oxides; they are *glass*, of nature's manufacture.

The technical names for rock-crystal and the various species of sand, are **SILEX**, **SILICA**, and **SILICIC ACID**. The most finely-powdered silex feels harsh and gritty between the teeth, is utterly tasteless, and insoluble in water. It may seem at first sight strange to call such a substance silicic acid, as it appears to be devoid of all acid properties. But it may be here observed that a chemist, by the word acid, "does not of necessity mean a substance possessed of an acid taste, and capable of reddening blue litmus-paper." (It may be noted that litmus-paper is a very delicate test for such acids as are soluble in water. The blue color is turned into red.) No substance insoluble in water, or some other liquid, can be possessed of taste. An *acid* is a combination of an element, usually with Oxygen or Hydrogen, possessed sometimes, though not necessarily, of a sour taste, but always of the power, under given circumstances, of forming a *salt* by union with a metallic oxide or base. Silica is a very powerful acid, although its properties as such are only displayed under the action of considerable heat. At high temperatures it is one of the most powerful acids with which chemists are acquainted. It has been observed above, that silica is naturally insoluble in water; nevertheless, it may be rendered soluble, by several of the great and potent agents which are ever silently in operation in nature. For the supply of very many plants, into the structure

of which it enters, and in which it seems to play the same part as the bones do in animals, silica must become soluble in the soil, or else the delicate stomata or mouths of the rootlets of plants would refuse admission to it. And that it does so become soluble, is certain. It is even found in spring and mineral waters. In the boiling Geysers of Iceland, it is contained in such quantities as to be deposited by them in porous masses, not very unlike stalactites.

The chemistry of silica is simply this. It is not an element, but a compound; in fact, the oxide of an element, called *silicon*. The latter is never found in a free state; prepared in the laboratory, silicon resembles a brown powder, destitute of metallic lustre. Its symbol is Si, and its equivalent 22. It combines with oxygen in one proportion, and forms silex or silica,—a definite compound of one atom of silicon, with three atoms of oxygen. The chemical formula of silicic acid is therefore Si O^3 . Its specific gravity is about 2.66; and it is only fusible by the oxy-hydrogen blowpipe.

Finally, silica is known to exist in two distinct forms, the soluble and insoluble. The soluble passes into the insoluble, as soon as it has once been separated from its solvent, and dried.

But rock-crystal is not glass. Glass is a fused mixture of combinations of silica, with several oxides; of silicates, as the salts of silica are called. As it would be impossible to understand the chemistry

of glass, without first considering the nature of the substances with which the silica is combined for its formation, I will at once proceed to describe them.

Wood-ash, pot-ash, and pearl-ash, are the names given to the more or less pure carbonate of potash of commerce. This salt, which consists of a combination of carbonic acid with potash, is exclusively supplied by the combustion of wood and other vegetable substances; its production, on a large scale, is therefore necessarily confined to those countries in which timber abounds. Thus, in the clearings of Canada and the United States, it is usual to burn the wood which cannot otherwise be employed, for the purpose of collecting the ash which remains. This ash is washed with water, and the washings boiled to dryness in iron pots,—hence the name *pot-ash*. When this potash is again dissolved in water, and the clear liquid decanted (poured off from the sediment) and boiled, the pearl-ash or carbonate of potash of the shops is obtained.

Pure carbonate of potash is a white granular salt, soluble in its own weight of water, fusible at a red heat, and possessing great attraction for water. The potash of the carbonate is a very powerful basic oxide, combining readily with acids, and forming salts. It is very acrid and corrosive, and is hence commonly called caustic potash. At a white heat it is decomposed by charcoal, and thus the metal *Potassium* may be separated from the oxygen, with which

in *Potash* it is combined. Potassium is a blueish-white metal of great lustre, having a strong tendency to attract oxygen, and to re-form potash. When simply exposed to the air, it gradually absorbs oxygen; if heated in the air it takes fire and burns. It even bursts into flame when thrown upon water, depriving that liquid of its oxygen, and liberating its hydrogen, — and it was justly considered as the most astonishing property of this metal, when first discovered, that it took fire when placed upon ice. When thus burned, potash is formed, and is found dissolved in the water.

The class of bodies to which potash (and soda) belong, is that of the *alkalies*, which are distinguished by their solubility in water, by their power of combining with acids and forming neutral compounds called salts, and by their property of changing, in a remarkable manner, the colors of certain vegetable matters. The words *alkali* and *alkaline*, so much in use, are of Arabic origin, and are derived from *kali*, the name of a vegetable species from which soda was formerly extracted; the Arabic article of perfection *al*, having been prefixed to express the superiority of the alkali over the plant which afforded it. Ammonia is also an alkali. This is usually called a volatile alkali, on account of its nature (see pp. 20, 21, and 22); while potash and soda are termed fixed alkalies, they not being volatile at a red heat.

The name *Kalium*, by which potassium is usually represented, will, after this explanation, be more intelligible. K is the symbol of potassium—the combining proportion or equivalent of which, is 40.

The oxide of kalium or potash is = KO ; its equivalent 48.

When one part of silica, and two-and-a-half parts of carbonate of potash are fused together, the carbonic acid is expelled, and a silicate of potash is formed, which is soluble in water, and known by the name of *soluble glass*. A concentrated solution of this in water, mixed with chalk or fine china clay, is sometimes used as a paint, to render wood, paper-hangings, and other like articles, incombustible.

When pearl-ash and a great excess of silex are melted together, a nearly insoluble silicate or species of *glass* is obtained.

But one of the constituents of glass is *Soda*. In the same manner as carbonate of potash is obtained by the combustion of land-plants, so in former times was all the carbonate of soda of commerce obtained from the incineration (burning to ash) of sea-weeds. *Barilla* and *kelp* were the names of the rough carbonate known in the markets, and twenty-four tons of sea-weed were required for the production of one ton of kelp. A very pure carbonate of soda, which, on account of its cheapness, has been made to supersede in many of the arts the far more expensive carbonate of potash, is now manufactured on an im-

mense scale in England, by the decomposition of sulphate of soda (Glauber salt).

The *carbonate of soda* of commerce is a salt, very large transparent crystals of which may be frequently seen in the windows of oil-shops. It contains a large per-centage of water, a portion of which it exhibits a tendency to lose, and thus we often see the transparent crystals covered with a white powder of anhydrous carbonate of soda. When heated, it melts in its water of crystallization, and, if the heat be continued, gives off all its water. The dry carbonate thus obtained is a white powder, soluble in two parts of water, to which it communicates a strong, disagreeable, caustic taste.

The *soda* of the carbonate is a very strong basic oxide or base, only second to potash in its affinities or powers of attraction. At a white heat, caustic soda may likewise be decomposed by charcoal, and the metal *Sodium* or *Natrium* obtained. It is silver-white, very soft, and oxidizes immediately on exposure to air. It melts at 194° . Its specific gravity is 0.972. The equivalent of Sodium is 24, and its symbol Na. Soda is a compound of sodium with one equivalent of oxygen, and is represented by the formula Na O.

The compounds of silica with soda are so similar to those of potash, that it is needless further to describe them. Suffice it to say, that, no matter how pure the materials employed, the glass resulting from the use of soda is always possessed of a *greenish* hue.

Lime is likewise used in the preparation of glass. Carbonate of lime, or mountain-limestone, forms, as is well known, whole ranges of hills in many parts of the world. Chalk, calcareous spar, and marble, are other names for varieties of carbonate of lime. It is almost insoluble in pure water, requiring as much as 10,601 parts to dissolve one of pure carbonate of lime. When mountain-limestone is heated intensely in the lime-kiln, it loses its carbonic acid, and becomes *oxide of calcium*, *lime*, *quick-lime*, or *caustic lime*, these being the various names by which the product is known. The pure kinds of mountain-limestone lose about 44 per cent. of their weight. *Lime* is a very powerful base, and very caustic. It requires for its solution 750 parts of water. Its most remarkable property is its strong tendency to combine with water. In fact, when a few drops of water are poured upon a piece of quick-lime, it falls down into a fine white powder, emitting at the same time a great amount of heat. This operation of *slaking* lime may be constantly seen wherever building operations are carried on; the heat generated in the process is frequently made use of by the workmen for the purpose of warming their tea or coffee, and it has been made use of for cooking meat. The emission of heat is caused by the union of the water with the lime; the former, becoming solid, gives off the heat necessary for retaining it in a liquid form.

Slaked lime is a compound of lime with water,

and is called in consequence a *hydrate of lime*. It contains 24 per cent. of its weight, of water. In the caustic state lime does not occur in nature, nor, when exposed to the air, does it long remain in that state. It first slakes, then gradually absorbs carbonic acid from the air, and becomes again converted into carbonate of lime.

Although, as we have seen, carbonate of lime is nearly insoluble in water, it is freely taken up when carbonic acid happens at the same time to be present. Since all natural waters contain carbonic acid in solution, it is to be expected that lime in this condition should be of very common occurrence; and such is found to be the fact, river and spring-water invariably containing carbonate of lime thus dissolved. When such a water is heated to boiling, carbonic acid is expelled, and the carbonate precipitated. And this likewise takes place at the ordinary temperature of the air, although more slowly. And thus the beautiful stalactites in limestone caverns, and deposits upon the ground in many places, are explained.

Lime, like potash and soda, is an oxide. It is a combination of oxygen with the metal *Calcium*. It is prepared artificially only with great difficulty, and is not known to exist in nature in an uncombined state. Calcium is a silver-white and very oxidizable metal. Its equivalent is 20; its symbol Ca.

The important oxide of calcium is represented by the formula Ca O , which at once indicates the nature of the combination. The symbol for carbonate of lime is Ca O, CO^2 .

Oxide of Lead, which may be prepared by exposing the grey powder which forms on melted lead to the further action of heat and air, until it acquires a uniform yellow color, is a most important agent in the manufacture of glass. It forms very fusible salts with silex, and as these are beautifully clear and colorless, its value for the purpose of glass-making may be readily conceived.

By further exposure of this oxide of lead to the action of heat and air, at a high temperature, though below its melting point, it attracts a further quantity of oxygen, and acquires gradually a fine red color. *Minium* or *Red Lead* is preferred in glass-making to the ordinary oxide or litharge, because the excess of oxygen over that of litharge, although given off at a red-heat, has the power of oxidizing and removing any organic impurities which may have become mixed with the various ingredients, and which otherwise would impair the brilliancy of the glass.

Glass, the manufacture of which it will, after this preparation, not be difficult to understand, is altogether destitute of *crystalline* structure. It is, essentially, a compound of silica with potash or soda, lime, and oxide of lead. The silica is em-

ployed in greater or less quantity, according to the purpose designed by the manufacturer. Fine white sand is usually employed; sometimes, ground flints, or the white pebbles so abundant in many rivers, are made use of. When the *purity* of the glass is of importance, carbonate of potash or soda is used; while for common glass, wood-ash, barilla, and kelp are sufficiently pure. The proportions of the raw materials will vary much, usually about half the weight of the silica being the proper amount. During the process of fusion, the carbonic acid of the carbonates escapes in bubbles; and the glass is ready for use as soon as the melted mass is free from the bubbles of escaping gas. A glass composed entirely of silica and potash, or soda, requires a very high temperature for perfect fusion; and this is the chief reason for the employment of litharge or of red lead. The fusibility is much increased, and the compound is not only more tenacious and workable when hot, but bears changes of temperature better. London *flint-glass*, so celebrated for its brilliant transparency, is prepared with oxide of lead; but, in consequence of its softness, it is very liable to become scratched. The composition of flint-glass, according to Faraday, is as follows:—

Silica	51·93
Potash	13·77
Oxides of lead	33·28
Impurities and loss	1·02
	<hr/>

The mixture of materials for glass is technically termed *fret*; their fusion is conducted in large crucibles, or glass-pots, made of the most infusible kind of fire-clay, which, in the case of lead glass, are covered by a dome at the top, and have an opening at the side, at which the materials are introduced, and the melted glass withdrawn. At a full-red, which is the working heat, the glass has a very tenacious consistency, and, as it scarcely adheres to polished metal, is easily worked with iron tools. The circular tables of *crown-glass* are made in the following manner: the workman having collected the proper quantity of glass, in the soft pasty state, at the end of his blowpipe, commences blowing, by which the lump is expanded into a kind of flask. The latter is fastened at bottom to an iron rod or puntil, by means of a little fresh glass obtained from the glass-pot, and the blowpipe is removed from the neck of the flask by the application of cold iron. The flask is suddenly made to assume the form of a flat disc or plate, by the centrifugal force induced by the rapid, wheel-like movement given to the puntil. Crown-glass or window-glass is made of soda, sand, and about six per cent of lime. (Fownes.)

Plate-glass is cast upon a flat metal table, and polished by machinery.

One of the most important parts of the glass-making process is that of *annealing*. This consists in arrangements for allowing the glass to cool very

slowly, else it is apt to be brittle and to *fly*, as it is called.

Tumblers and wine-glasses, when first bought, are treated by careful housewives in the following manner. They are put into cold water, upon which a little hay is placed, and this is carefully and slowly raised to the boiling point. If the water is then allowed to cool slowly, the glass thus treated will stand any sudden change of temperature. The use of hay or such materials is to prevent any sudden contact of cold: in fact to allow the cooling of the water to proceed evenly.

It has been already stated, that the use of potash secures a clear, and, indeed, the only perfectly colorless glass. The very beautiful *Bohemian glass* consists, according to Mitscherlich, of—

Silica	60·0
Potash	25·0
Lime	12·5
Manganese, alumina, and loss . .	2·5
	<hr/>
	100·0

The various *colors* are communicated to glass by metallic oxides. Oxide of manganese produces an amethyst color; oxide of cobalt, a blue; oxide of gold, a purple; sub-oxide of copper, a ruby-red; oxide of copper, a green; oxide of silver, a yellow; oxide of chrome, a green; oxide of iron, a bottle-green, &c. In glass-painting the oxides are applied

to the surface of the glass, which is then re-heated until fusion of the coloring-matter in the glass-surface takes place. An opaque white appearance is given to the enamel of watch-faces, by oxide of tin.

CHINA, STONEWARE, AND EARTHENWARE.

The art of making POTTERY is intimately connected with the subject of glass. There are few branches of industry of greater antiquity than that exercised by the potter. The plastic qualities of clay, and its hardening when exposed to heat, are properties which suggested, in very early times, its application to the making of utensils for the manifold purposes of daily life.

The *slates* and *tiles* with which our houses are roofed, the *bricks* of which they are built, the *china* of which our cups and saucers, the *earthenware* of which our plates are made, are nothing more than varieties, more or less pure, of the clays and marls so abundant on various spots of the earth, as to have induced men to build their cities upon them. What then is *Clay*?

Pure *clay* is a beautifully white substance composed of silica and alumina. It is a true silicate. *Alumina* (contained in alum) or *argil*, as it is sometimes called, is the *oxide* of the metal *Aluminum*. Native alumina constitutes the *sapphire*. The *oriental ruby* and *topaz* are red and yellow varieties

of this earth. *Corundum* and *emery* are minerals consisting of alumina, with less than two per cent. of oxide of iron and silica. The crystalline varieties of alumina are only second to the diamond, with respect to hardness.

Aluminum is another of those rare and little known metals. It has a grey color, and perfect lustre. Its equivalent is 14 : its symbol Al. When heated in air, it takes fire, and burns with brilliancy, producing Alumina.

Alumina, as prepared in the chemist's laboratory, is a white, tasteless, coherent mass, possessing great mechanical attraction for water, which it greedily absorbs. Unlike potash, soda, and lime, it is a very weak base. Infusible in all furnaces, it yet yields to the heat of the oxy-hydrogen blowpipe.

Alumina must not be confounded with clay,—a very common mistake. The only clay suitable for the manufacture of *china*, is the so-called *china-clay*, or *kaolin* ; and even this substance is the result of the decomposition of more compound silicates than clay. The ancient unstratified rocks, but more especially granite, and porphyry, contain largely a mineral, *felspar*, which, under certain circumstances, and in the course of time, decomposes, loses its original hardness, and becomes a mass of soft, white, earthy matter, resembling wet slaked lime. The exact nature of the change of felspar into clay is not precisely known; the felspar, a defi-

nite combination of silicate of alumina with silicate of potash, acted upon by the carbonic acid of air, and by rain, parts with the silica and potash, and becomes converted into china-clay.

In the manufacture of *porcelain*, great skill is required in the selection of materials. No oxide of iron must be present in the clay to mar the perfect whiteness of the china. As the clay has to undergo intense heat, and that long-continued, no easily fusible materials must be left in, or added to it, beyond what is necessary to the production of a semi-translucent glassy texture, and to the prevention of too great shrinking. To effect all these objects, proper proportions of crushed flints and of felspar are intimately mixed with the clay, and great care is taken that the materials, when mixed with the proper quantity of water, form a uniform pasty mass, free from grit. China-ware is formed from it, either on the potter's wheel, or in moulds of plaster. These are then air-dried in a warm room, and being enclosed in baked clay cases, somewhat resembling band-boxes, and called *seggars*, are ranged in the furnace. This is a structure made of brick (somewhat resembling a kiln), having several fire-places, and surrounded by a lofty dome. The cases are so closely packed, as only to leave space for the full play of the flame. Here the ware is kept red-hot for many hours, and the fires are allowed to die out before the seggars are removed.

Biscuit-ware is thus produced. This is afterwards glazed, by dipping it for an instant into a tub containing a mixture of certain proportions of felspar, or of gypsum, silica, and a little porcelain clay, diffused through water to a creamy consistency. The ware absorbs the water, and the powder remains evenly spread over its surface. It is once more dried, and then exposed to a temperature sufficiently high to melt the glaze.

The *colors* employed in painting china are the same metallic oxides which are used for painting or staining glass. The colors are mixed with oil of turpentine or oil of spike lavender, and are applied with a camel-hair brush. When several colors are used, those that bear a high temperature are first laid on, and burnt in, before those which can stand only a lower heat are applied.

The *gilding* is generally done by applying finely-divided gold, mixed up with gum-water and borax (a salt of soda and boracic acid). Upon the application of heat, the gum burns off, and the borax, vitrifying upon the surface, causes the gold to adhere firmly. It is afterwards burnished.

STONEWARE

Is a coarse kind of porcelain, containing both oxide of iron, and lime, to which it owes its color and its partial fusibility. The *glazing* is effected by throwing common salt into the heated furnace.

This is volatilized, and decomposed by the joint agency of the silica of the ware and of the vapour of water always present. Hydrochloric acid and soda are produced, the latter forming a silicate which fuses over the surface of the ware, and gives a thin, but excellent glaze. (Fownes.)

EARTHENWARE.

The pottery commonly called *Staffordshire ware* is made from a commoner white clay than porcelain-clay, mixed with ground flints in considerable quantities. The mode of manufacture is the same as in the case of china, but the glaze is different. It consists of a mixture of about sixty parts of litharge, ten of clay, and twenty of ground flint, diffused in water to a creamy consistency. This glaze is very fusible. The painting on this ware is usually blue, in consequence of the cheapness, and the facility of application of the oxide of cobalt. The pattern is first printed off upon paper, which is applied to the plate or other article before glazing. When the ink is dry, the paper is washed off, and the glazing completed.

The whitish opaque glaze, which we see on the coarser kinds of earthenware, contains the oxides of lead and tin, and they are therefore unfit for culinary purposes.

QUESTIONS ON CHAPTER VI.

By whom was glass discovered? How may it be supposed to have been discovered? Was glass known to the ancients?

What two cities enjoyed a great reputation for glass? Do you remember the sum paid by a Roman emperor for two small glass vessels? What is the history of the Portland Vase? Describe it?

What city was most distinguished for its glass in the thirteenth century?

What state followed in the wake of Venice?

Do we know who introduced the glass manufacture into England? What about the Druids?

Where was window-glass first manufactured in England? And flint-glass? In what year? Who patronized the Venetian artizans? About what year? Had this patronage any beneficial effect?

What scientific instruments are alluded to by the writer in the Rambler, a paragraph from whom is given in this chapter?

Is glass a natural product? What in nature resembles it most? What is the opal composed of? Name some of the varieties of silix.

What is the use of litmus paper?

What is an acid? Why is silix an acid? What are the three names possessed by pure sand? Describe the leading properties of silica? Is it soluble in water? Is it ever thus met with in nature?

What is the chemistry of silica? What is silicon? What are its properties? What is the symbol of silicon? What is its equivalent? What is the composition of silica? Write down the formula. Is silica fusible?

Is rock-crystal glass? What is glass?

What materials are used in the formation of glass?

What names are given to the more or less pure carbonate of potash? How is it obtained? Why is it called potash? What is pearl-ash?

Describe the appearance and properties of pure carbonate of potash?

What is the nature of Potassium? What is the most striking characteristic?

What is the name of the class of bodies to which potash belongs? What is the character of the class? What is the derivation of the name of the class? Do soda and ammonia belong to the same class? What difference is there between potash and ammonia?

What is the symbol of potassium? Its combining proportion?

What is potash composed of? Express it symbolically?

What is soluble glass composed of? What use is made of it?

What other constituent is there in glass besides potash? Whence used the supply to be obtained? Is it so now?

Describe the appearance of carbonate of soda. What are its properties? How may the metal sodium be obtained? What other name does it go by? What are its properties? What is its equivalent? Its symbol? What is the formula for soda?

What color is soda-glass?

Is lime ever used in the preparation of glass? Is carbonate of lime abundant? Name some of its varieties? Is it soluble in water? When heated to redness, what becomes of it? What are the names of the new product? Is the operation of combining lime with water of frequent occurrence? What is the technical name. Is heat given off in the process? What is the reason?

How much in weight does pure mountain-limestone lose? Is lime a powerful base? How much water does it require for solution?

What is slaked lime? What do chemists call it? How much water does it contain? Does it ever occur native? What changes does it undergo in air?

How is carbonate of lime taken up by water? Is it ever contained in spring-water? How are stalactites formed?

What is lime chemically? What metal is the oxygen combined with? What is its character? What is the weight of an atom of calcium?

How may lime be represented chemically, as regards its composition?

What is the symbol of carbonate of lime?

How may oxide of lead be prepared? What is the character of silicates of lead?

How is red lead obtained? Why is it preferable?

Has glass a crystalline structure? What is it essentially a compound of? What varieties of silica are employed? When the purity of the glass is an object, what salt is employed? Otherwise? What is the proportion of silica? Describe the chemical decomposition which takes place when siliceous earth and carbonate of potash are fused together? What oxide is most largely contained in flint-glass? What is the chief beauty of this kind of glass? What are its faults?

What is the technical name for the mixture of materials for glass? How is their fusion conducted? How is crown-glass made?

How is plate-glass cast?

What is the object of the annealing process?

How are the colors communicated to glass?

What oxide communicates the opaque white to watch-faces?

What are the principal properties of clay?

What is clay? Name a few household articles made of clay?

Describe the properties of aluminum? What is its equivalent? What is alumina?

What appearance does it present? Is it fusible?

Are alumina and clay synonymous? What is the only suitable clay for china? From the decomposition of what mineral is it obtained?

Why may not iron be present in any of the materials? Describe the process?

How is the glazing of the biscuit-ware performed?

How are the colors produced?

Describe the gilding process?

In what respects does stoneware differ from porcelain? How is the glazing accomplished?

From what is Staffordshire ware made? Does the manufacture differ from that of china? How is the glaze made?

What materials used in the glaze of certain kinds of earthenware render the rejection of them in kitchen-use advisable?

CHAPTER VII.

CHEMISTRY OF SOAP.

IN a chemical point of view, the manufacture of soap is extremely interesting, and forming as it does one of the most important articles of domestic use, a short account of its composition, and the process of its manufacture, should not be omitted in a work professing to illustrate household chemistry.

The Latin word *Sapo*, and the Greek *Σάπων* (*Sapōn*), signifying soap, are undoubtedly derived from the German; for we find the corresponding word *Sepe* is still used in the Low German dialect. Pliny, who makes the earliest mention of soap, declares it to be an invention of the Gauls, though he prefers the German to the Gallic soap. Both hard and soft soap were in use among the Germans. Pliny states that it was made from tallow and ashes, and that it was employed both as a medicine and for washing clothes.

It appears certain that in remote periods clothes

were cleansed by being simply rubbed or stamped upon in water, without the addition of any extraneous substance. In the sixth book of Homer's *Odyssey*, we read that Nausicaa and her attendant washed their clothes by treading upon them with their feet, in pits which they had filled with water.

At a later period mention is made of a lye of ashes being employed for washing, and that with it oil and wine-jars were cleansed; and there can be little doubt that a solution of wood-ashes, or of impure carbonate of soda, was used for the purpose.

The ancients appear also to have employed at least one description of plant with a saponaceous juice, as a substitute for soap, but the precise plants used cannot be ascertained; and it is also certain that they made use of fuller's-earth, much oftener than is done at present. (*Beckman's History of Inventions.*)

The chief soaps manufactured in this country are:—white soap, yellow soap, mottled soap, brown soap, soft soap, and silicated soap.

The subject of saponification will not be difficult to understand, the reader having had some preparation in the numerous allusions to the subject. At pages 49 and 50 somewhat of the nature of oils and fats has been described; and although the information already given must be somewhat expanded, no new terms will be required in the explanation of the subject.

Our knowledge upon the subject of oils and fats is very considerable; no branch of chemistry having been studied with more decided success. These substances form a natural group, in which the animal fats agree closely with the vegetable. All oily substances may be divided into *fixed* and *volatile*. When dropped upon paper, both kinds produce a greasy stain, which *disappears* when heated, in the case of a volatile oil, but *remains* when produced by a fixed oil. Of course, then, the volatile oils are alone odorous; and wherever a fixed oil is perceived to be possessed of smell, we may be sure of the presence in it of a volatile oil. This is well illustrated by the case of butter. The margarine and oleine have no smell, but the butyrine, amounting to three per cent. (see page 74,) gives both smell and taste.

A very important property of oils is that of drying or not drying by exposure to air. The terms *drying* and *non-drying* can only be applied to fixed oils, as a volatile oil (for example, attar of roses) would fly off in vapour. All oils are altered by exposure to air. In the case of the oils used in making paints (linseed, rape, walnut, and poppy), they absorb oxygen, and become hard and resinous. All animal fats and oils, as well as olive and palm oil, likewise attract oxygen, which makes them acid and rancid, but never dries them.

As in the case of the metals, so in oils, we find a

great difference as regards hardness. Between the very fluid olive oil and hard mutton suet, there lie the greatest varieties of consistency. The difference, as I have already had occasion to explain, depends upon the proportion in which the great fatty principles are mingled. It is as easy to mingle them in any proportions, as to separate them. Thus, olive oil, exposed to a temperature a little above the freezing point, deposits a solid fat, and separates into two distinct substances: *oleine*, a liquid, and *margarine*, a solid substance of pearly lustre, separable by simple pressure from the oleine. Again, if suet be pressed between folds of blotting paper, whilst the paper will be found stained with oleine, the suet itself will have become much harder, less fusible, and less tenacious. It consists now of *margarine* and *stearine*, the latter a white and lustrous substance.

In the process of saponification, the acids of the three substances, oleine, *margarine*, and *stearine*, combine with the potash or soda; the essentials in this process forming soap, while the glycerine is set at liberty. Soap is therefore a true *salt*, the acid being oleic, *margaric*, or *stearic*, the base potash or soda. When mutton fat or tallow is boiled with caustic potash or soda for a time, it gradually dissolves, forming, with the alkali, a transparent viscid mass, soluble in water.

The alkaline ingredients of soap are two-fold. At page 173, I have spoken of *carbonate of potash*

as being used in the manufacture of glass. *Caustic potash* is prepared from it in the following manner. One pound of carbonate of potash is dissolved in ten pounds of boiling water in a clean iron vessel. Into it is stirred, by degrees, three-quarters of a pound of quick-lime, previously slaked. After a few minutes' fierce boiling, it will be found, on examination, that the carbonate of potash has parted with its carbonic acid to the lime, which has become converted into carbonate of lime, or chalk, and a solution of caustic potash in water has been obtained. It is removed from the fire, and will be found, after the lapse of a very short time, to consist of a clear solution of potash, which should be carefully poured off from the heavy sandy precipitate of chalk, and excess of lime. The solution possesses, in the highest degree, the properties termed alkaline. It dissolves the skin, when subjected to its action. It restores the blue color to reddened litmus paper; combines with, and neutralizes the most powerful acids, and is possessed of a most peculiar nauseous and biting taste. It unites with fats and oils to form soap, as explained; hence the term *soap-lye* given to the solution of caustic potash.

Pure caustic potash freed from mechanical water, is, like slaked lime, a true hydrate, and is represented by the formula K, HO .

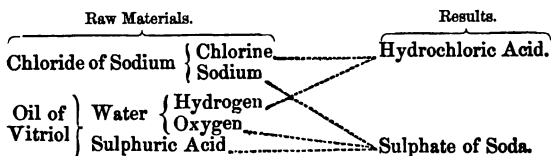
On account of its greater cheapness, *caustic soda* is, however, more generally used in the manufacture

of soap than potash. At page 169, I have indicated the source from whence all carbonate of soda is now obtained. Until within the last thirty years, nearly all the soda of commerce was obtained by reducing marine plants to ashes. Barilla of good quality contains about $\frac{1}{2}$ of its weight of soda. It used to be an important article of commerce, until the salt duties were repealed. The common process for obtaining soda by the decomposition of sea-salt, was invented by a French gentleman of the name of Leblanc, towards the close of the last century. The supply of Spanish barilla being cut off from France during the cessation of the commercial intercourse between France and Spain at the time of the first great French Revolution, the national convention of France applied to the French chemists for a new source of soda. M. Leblanc hit upon a plan which is now carried on upon a prodigious scale in both England and France. The salt duties alone prevented the early adoption of the plan in England; but since its repeal, both kelp and barilla have become valueless as sources of soda.

The materials employed in the soda manufacture are: chloride of sodium (common salt), sulphuric acid (oil of vitriol), small coal, carbonate of lime (chalk), and charcoal.

The first step is to convert the *chloride of sodium* into *sulphate of soda*—to change sea-salt into Glauber salt. This is accomplished in the decomposing

furnace, by sulphuric acid. The chemical change which the salt undergoes, may be expressed by the following diagram :—



From which it appears, that the water contained in sulphuric acid is decomposed; its hydrogen combines with the chlorine, whilst its oxygen oxydizes the sodium, and enables it to combine with the sulphuric acid. The dry sulphate, technically known as the salt-cake, is, in the next place, calcined (burnt) with chalk and small coal. The proportions recommended by Dr. Ure are, 10 parts of salt-cake, from 11 to 12 parts of chalk, and five of coal. The product of the calcination, a process unnecessary to describe in a work like Household Chemistry, is known as British barilla, and black-ash; it contains about 23 per cent. of soda. By the fusion of the sulphate of soda with the coal, the former, parts with the whole of its oxygen to the carbon and hydrogen of the coal; carbonic oxide and water are formed and dissipated by the heat, while sulphuret of sodium remains. But by the admixture of chalk, a still further change takes place: carbonate of soda and sulphuret of calcium are formed, which remain mixed up in the British barilla with coal and other

matters. The remaining part of the process is effected by the agency of water, subsequent evaporation, and calcination.

To obtain the crystallized carbonate of soda, the purified ash is dissolved in hot water, and allowed to crystallize in shallow pans of iron or lead. The crystals are composed of:—

Soda	21·81
Carbonic acid	15·43
Water of crystallization	62·76
	<hr/>
	100·00

Exposed to air, they fall to powder, and, at the same time, lose some water of crystallization.

The white powder sold by druggists as carbonate of soda, which is employed in making effervescing draughts, and in removing acidity from beer, is a *bicarbonate of soda*, inasmuch as it contains *two* equivalents of carbonic acid to one equivalent of soda.

The description of the process employed in the manufacture of caustic potash applies to that of soda. In preparing a lye for the soap-manufacture, the mixture of lime and carbonate of soda or soda-ash is placed in large cast-iron vats, and covered with water, and after some hours, the lye is withdrawn through a plug at the bottom of the vat. A purer caustic soda solution may be prepared by boiling in a clean iron-pot a solution of two parts of crystallized carbonate of soda, in eight parts

of water, with about one part of slaked lime, until a little of the liquid ceases to effervesce on addition of acid.

Soaps are either hard or soft; the former being compounds of fats or oils with soda—the latter with potash. Soft soap is made with potash and drying oils, either alone, or mixed with tallow, and other coarse and fatty matters. The best hard *white soap* is made from olive oil and soda. The oil is mixed with the lye, and boiled in an iron pot, until the fat is completely saponified, which may be known by its becoming clear and transparent. The boiling is continued until the soap begins to separate, and this result is accelerated by the addition of common salt. *White soap* is sometimes composed of tallow and soda. *Yellow soap* is made of tallow, resin, and soda, a little palm-oil being occasionally added. The peculiar appearance of *mottled soap*, formed of tallow, kitchen-stuff, and soda, is communicated by dispersing the lees through it towards the end of the operation. *Brown soap* is made from palm-oil, resin, and soda.

The so-called *silicated soap*, of which large quantities are now manufactured, is made by combining silicate of soda, or soluble glass, with hard soap, in the hot pasty state; from 10 to 30 per cent. may be introduced. Such soap possesses, according to Dr. Ure, very powerful detergent qualities, but it is apt to feel hard and somewhat gritty in use. The sili-

cate of soda, with excess of soda, is obtained by boiling ground flints in a strong caustic lye.

Many substances are used to *adulterate* soap, such as clay, potato-starch, &c., for which improvements, as they are termed, numerous patents have been granted (*Beckmann*).

Soap is *soluble* in pure soft water, without decomposition. But when waters contain gypsum, which, with other saline constituents, make water hard, then it is decomposed. At first the water becomes full of flakes, and the cleansing properties of the soap are not brought into play until the action of the acids of the salts, present in the water, upon the potash or soda in the soap, has ceased. Thus, when gypsum, or sulphate of lime, in solution, is brought into contact with soap, the potash or soda combines with the sulphuric acid, and an insoluble lime-soap separates in white flakes from the water. This fact explains the importance of *soft* water for domestic purposes, and indicates the cause of the great waste of soap by the use of *hard* water.

The *cleansing* property of soap is due to the fact, that the greater part of the dirt upon our linen, or our clothes, consists of oily perspiration, grease, or of dust which that grease fixes, and which either cannot be removed at all, or but very imperfectly, by washing in water alone. But if soap be used, its alkaline character displays itself; the grease

unites with the potash or soda, and forms, in fact, a soap, which may then be removed by water.

Fuller's-earth, a white clay, acts, partly by scouring, partly by absorbing the greasy dirt.

If cleanliness be, as the proverb hath it, next to godliness, the manufacture of soap must needs be an important one; so much, at any rate, does the comfort of a community depend upon this useful article, that the consumption of soap has been considered to afford a good test of the comparative civilization of nations. In this country it is manufactured on a very large scale; and great quantities are annually exported to foreign countries. Owing to its universal use it has been considered a good means of raising a revenue; and in England, since the reign of Queen Anne, it has been more or less heavily taxed. There is no doubt that taxation acts as a considerable check upon the free use of soap, and at the present time, when such general attention is directed to all matters affecting the sanitary condition of the population, the importance of the unrestricted use of soap is generally felt. The quantity consumed, in spite of restrictions, is known to be very large; in 1848 it amounted to nearly 190,000,000 lbs.

QUESTIONS ON CHAPTER VII.

What is the word soap derived from? Where was it invented? What does Pliny state with reference to it?

How were clothes washed in remote periods? Do we read anything about washing in Homer?

What juices did the ancients employ as substitutes for soap? Did they ever use fuller's earth?

What kinds of soap are manufactured in England?

Is the subject of saponification difficult to understand? What do you know of it?

Do the animal fats differ from the vegetable? Into what divisions may all oily matters be divided? What distinguishes them as regards volatility? Which oils are alone odorous? What example have we in the case of butter?

What do we mean by drying and non-drying oils? Do animal fats attract oxygen? Do they harden?

Is there any difference in the hardness of fats? In what consists this difference? Is it easy to mingle the various fatty matters? Give examples.

Describe the difference between oleine, margarine, and stearine?

Explain the nature of the change which fats undergo when boiled with potash or soda.

Is carbonate of potash used in the glass-manufacture? What alkaline ingredients are used in the soap-manufacture? How is caustic potash prepared? What are its properties? In what respect is pure caustic potash like slaked lime?

Is caustic soda much used in the soap-manufacture? Why? What was the original source of soda? Is barilla now much employed? Why not? What led to its disuse? Who discovered the new method of manufacture? What prevented its immediate introduction into England?

What are the materials employed in the manufacture?

What is the first step in the process? Can you explain it? Write the change down upon your slate or upon paper. By what name is the dry sulphate known? What is the next

step? What changes do the materials undergo? How is the remaining part of the process accomplished?

How is crystallized carbonate of soda obtained? What does it consist of?

Is there any other carbonate? What is its correct name? What is it used for?

How is the soda-lye obtained? Describe a method of preparing a purer kind of lye.

How many kinds of soap are there, as regards texture? How is soft soap made? What materials is the best hard white soap made from? How is it made? How is mottled soap made?

What is silicated soap? What are its properties?

What substances are used to adulterate soap?

Is soap soluble in pure water? Explain the nature of the decomposition which soap undergoes in hard water? What does this fact prove?

To what is the cleansing property of soap due?

How does fuller's earth act?

Is the soap-tax judicious? How much soap is used in England?

CHAPTER VIII.

THE CHEMISTRY OF HOUSEHOLD METALS.

THE grand store-house of the *metals* is the earth, which, however, as a rule, does not contain them in the form in which we are familiar with them, known as *native*, but in combination—either with one another, with oxygen, or with sulphur. When combined with each other they are termed *alloys*; in combination with oxygen, *oxides*; and with sulphur, *sulphurets*.

The number of metals known to chemists is forty-six, but those with which we should endeavour to familiarize ourselves, as being most generally useful, are only eight in number—viz., *gold, silver, quicksilver, zinc, lead, tin, copper, and iron*. All of these are distinguished by certain physical properties.

Their most striking character is what is commonly termed *metallic lustre*. The thinnest leaves of metals intercept the passage of light so com-

pletely, that this property is, no doubt, connected with, if not dependent upon, the degree of *opacity* which all present.

Metals are *not soluble* in water.

The difference of *specific gravity* in metals is most remarkable. But before adducing examples, I will further explain what is meant by the term. It is obvious that different pieces of the same substance will vary in *weight*, according to their size; but a small piece of gold will weigh much less than a large piece of cork, which would really be lighter, if the two were exactly the same magnitude. In all scientific investigation of substances, it is highly important to know what would be their *relative weights*, if they were of the same magnitude; or, what is still more convenient, their relative weight compared with some accepted standard. Compare a piece of iron with a piece of the common standard of exactly the same size, and suppose the standard to weigh 1, the iron will be found to weigh 7·8, or nearly 8 times as heavy. *These numbers represent the specific gravities of iron and the standard of comparison*; because if equal pieces of them of any other size were taken, their *relative weights* would be the same, though their absolute weights would be less or greater than those of the first pieces, according as they were smaller or larger. To obviate the necessity of reducing a new substance to precisely the same size of another, for the purpose

of comparing their weights, we adopt the following plan. If we immerse a piece of a substance, no matter what be its form, in water, it will displace a quantity of water exactly equal to itself in bulk. The substance so immersed is, in some measure, supported by the water pressing upwards against its under side; it consequently loses weight, proportioned precisely to the bulk of water displaced by the substance. Hence if the *water* be assumed as the *standard*, by weighing a body first in the air, and then again when immersed in water, the difference of the two weights is the weight of a body of water precisely equal in bulk to the body. By these means, the specific of the body or its relative weight, as compared with the standard (perfectly pure distilled water of a certain temperature), is ascertained. The specific gravity of metals varies exceedingly. Whilst potassium and sodium are lighter than water, gold is upwards of nineteen times as heavy.

In point of *color*, we have, fortunately, in the household metals all the varieties which the metals present. Copper is red, and gold yellow, but the rest present a great degree of uniformity, ranging between the brilliant whiteness of silver and the dull grey tint of lead.

In *fusibility*, or the degree of heat at which they melt, metals differ most widely. From quicksilver, which is liquid at all ordinary temperatures, to

pure iron, which requires the heat of a blast furnace; and from this again to metals of the nature of platinum, which is infusible in furnaces,—a variation of several thousand degrees of heat is to be found. Some metals soften and assume a pasty state before they become liquid. This is the case with iron, which thus admits of being welded, or united together without solder. Thus a bundle of small pieces of iron, when heated to redness, may be joined together into one solid lump by a few powerful strokes of the hammer. It is this property of fusibility which enables us to separate some metals from their dross, and which enables us to form every variety of instruments from them when so obtained.

There can be little doubt that metals are capable of assuming all the three forms of matter. Quick-silver boils and *volatilizes* at a temperature much below red-heat, and becomes a *solid* at 39° below the zero of Fahrenheit. Were a sufficient amount of heat obtainable, even those metals which now appear exceptions would, doubtless, be found to follow the same rule.

All metals unite with *oxygen* and *sulphur*, though with different degrees of readiness; in these states,—as *oxides* and *sulphurets*—they are generally found in nature. When the metals occur nearly pure, they are then said to be found *native*.

The sulphuret of lead, or galena, is the most

abundant ore of lead; but gold is always found native. Metallic ores do not generally compose large beds or extensive strata in the crust of our globe, but are usually found in clefts, rents, or fissures, called *veins*. The process for getting the ores out of the veins is called *mining*—a term also applied to the getting of coal, salt, &c. The mode of proceeding varies. The mining operations are the simplest when the vein is in strata, composing hills, or rocks, or mountains. If the vein be exposed at the surface of the ground, the mineral is simply dug out, and the excavation thus made serves as a passage to the interior of the mountain, in following the vein. When the vein does not appear externally, or when it takes a new direction, after being followed for some distance, access to it is obtained by *adits* or *levels* (horizontal galleries), dug from the sides of the hill, till the vein is arrived at. Similar galleries are also sometimes constructed to carry off the water which drains through the higher part of the mountain, and which would otherwise impede operations. When the mineral lies in strata considerably below the surface of the earth, then a perpendicular pit or *shaft* (like a well) is sunk to the requisite depth; and from the bottom or sides of this, horizontal galleries are carried to the beds or veins or strata sought. To afford a support for the superincumbent mass of earth, or rock, which is left without any, by the

excavation of the mineral, regard must be had to its value. When the mineral is valuable, the *roof*, or cavern overhead left by the removal of the ore, is propped up by timber or pieces of masonry; but in mines of coal or salt, the whole bed is not dug out, but masses of it are left like columns, to support the roof of the mine. Of course the ventilation of mines is important. The mode usually adopted is to cause a current of fresh air, from the surface of the earth, to descend one *shaft*, or one half of a shaft, to supply the place of the impure or noxious air, which is caused to rise through another shaft, or through the other half of the same. This ascent of impure air is effected in most cases by large fires made at the bottom of the shaft, the air in which, being thereby heated, ascends, as all hot air does, and causes an upward current, supplied by the air of the mine; and to obviate the formation of a vacuum, fresh air must descend into the mine by another passage. (The only real safety to the poor coal-miner consists, after all, solely in complete ventilation of his place of work.)

Some metals possess the property of *malleability*, or the power of extension under the hammer, to an amazing extent. Of this, gold leaf is a remarkable example. Zinc stands in the middle, between the malleable and brittle metals. Arsenic is entirely destitute of malleability; instead of being flattened out by a stroke of the hammer, it would fly into pieces.

Now, *ductility* differs from malleability, as it involves the principle of tenacity, or the power of resisting force. The art of *wire-drawing* depends upon this ductile property of metals.

Lastly, it may be said that most metals are capable of assuming regular forms, or of *crystallization*. The cause of crystallization is not certainly known. When a mineral yields crystals of more than one form, one of these, and generally that from which the others can be most readily obtained, is called the *primitive crystal*, and the others are considered as modifications of it.

1. GOLD. Latin, AURUM. Symbol, Au: Sp: gr: 19.26, Water being as 1.00. Equivalent, 200.

Although traces of this noble metal are to be met with in every country in Europe, yet the labor of obtaining it is so great, as to render it the most expensive of all metals. It is always met with in the metallic state, usually associated with quartz and other substances, and sometimes beautifully crystallized.

In the time of Queen Elizabeth, it was found in considerable quantities in the alluvial soil near the lead-hills of Scotland, and in Cornwall in several of the *stream-works*. It is also found in County Wicklow, Ireland, but the cost of labor exceeds the value of the gold.

The richest mines in Europe are those of Hun-

gary and Transylvania, there being no less than forty worked in these provinces, producing annually about 50,000 ounces of gold. The veins, too, of these mines are the largest in Europe, being rarely less than from eighteen to twenty-five feet, and in some parts upwards of one hundred and twenty feet thick. They are, however, not extensive.

In Africa, where, from the limited population and want of cultivation of the people, labor is worth little, considerable quantities of gold are obtained by the negroes, by washing the sands of rivers.

In the Russian provinces in Asia, gold is found in ever-increasing quantities, and it is from this source that, of late, Europe has been supplied.

Immediately after the discovery of America by Columbus, it was observed that the natives of Hispaniola wore ornaments of gold. The quantity, however, must have been small, for, from 1492 to 1500, only £52,000 of gold and silver were sent to Europe. To 1519, the annual produce of gold was never greater than £52,000. Cortez at this period conquered Mexico, and he obtained at Chalco, as presents to himself, £70,000 sterling in gold. The celebrated mines of Potosi were discovered accidentally by a Peruvian. Chasing some chamois among the rocks, he laid hold of a small shrub in his ascent, which gave way, and disclosed an immense vein of silver, since called "*La Rica*," or

"The Rich." The Indian kept his discovery a secret, and only had recourse to it to supply his wants; but the improvement in his circumstances attracting attention, his companions drew the secret from him, and revealed it to the Spaniards. The annual produce ever since has been equal to £280,000 sterling. In the Brazils gold was first known to exist in 1543; but the first ore found by a white man in that country was in the year 1693. This discovery led to the colonization of the Minas Geraes, and to all those evils resulting from the lust of gold, with details of which the history of South America abounds. Dr. Walsh mentions that, at a very early period, "two parties meeting on the banks of the river, where San José was afterwards built, instead of agreeing in their objects, and pursuing together their operations, set upon each other like famished tigers. A bloody encounter ensued, in which many were killed on both sides, and the river was from thenceforth called the Rio das Mortes, or the River of Death. The vicinity of this river," proceeds our authority, "everywhere attests the extensive search for gold formerly pursued here, as it was for a length of time considered one of the richest parts of Brazil, from the profusion of the precious metal found on its surface. All the banks of the stream are furrowed out in a most extraordinary manner, so as to be altogether unaccountable to one unacquainted

with the cause. The whole of the vegetable mould was washed away, and nothing remained but a red earth, cut into square channels, like troughs, with a narrow ridge interposed between them. Above was conducted a head-stream of water, let down through these troughs, which were all on an inclined plane. The lighter parts of the clay were washed away, and the gold remained behind."

That California is a land of gold, all know.

To us, the discovery of it in Australia is of more importance. We owe the suggestion of the probable presence of gold in that country, to Sir R. Murchison. His remarks, having found their way into the Australian newspapers, induced a Mr. Smith to search for it. He found gold, and offered to disclose his discovery to the government on certain conditions, with which the latter did not think proper to comply. It remained for Mr. Hargraves to re-make the discovery, and to reap the reward which should have been Mr. Smith's.

This first discovery was made in the banks of the Summer Hill Creek and the Lewis Ponds River, small streams which run from the northern flank of the Conobalas down to the Macquarrie. The gold was found in the sand and gravel accumulated, especially on the inside of the bends of the brook, and at the junction of the two watercourses, where the stream of each would be often checked by the other. It was coarse gold, showing its parent

site to be at no great distance. Shortly afterwards gold was discovered in several other localities, especially on the banks of the Turon, some distance north-east of the Conobalas. At the head of the Turon river, among the dark glens and gullies in which it collects its head-waters, in the flanks of the Blue Mountains, the gold got "coarser," occurring in larger lumps or nuggets, but these being more sparingly scattered. The further discovery of gold ensued as a matter of course.

It is found usually in the drift clay, sand, and gravel, or lying loose on the surface of the earth. The superficial drift in which the diggings have been carried on, varies in thickness from a few inches to twenty or thirty feet.

But I have already dwelt too long upon the subject, and must refer for further information to the "Lectures on Gold,* for the Instruction of Emigrants about to proceed to Australia."

For the purpose of separation, a quantity of the auriferous sand or clay is taken and washed with water, when the gold, by its own weight, sinks to the bottom, and thus, by repeated cleansing, the gold-dust of commerce is obtained.

As this appears a very simple process, I subjoin the few words of advice given by Mr. Jukes to intending emigrants: "Gold-digging is very hard

* These admirable lectures have been published by Mr. David Bogue, Fleet-street, at the low price of half-a-crown.

work—just such work as you see navigators at in a railway cutting, or brickmakers in a brick-pit. You must work hard all day, lie hard all night, with but little shelter, often with scanty food, and with nothing of what you have probably been accustomed to consider necessary comfort.”

When gold is imbedded in stone, it is stamped to powder, and shaken in an apparatus with mercury and water; a combination of the two metals, called an *amalgam*, is formed, after which the mercury is separated from the gold by distillation.

Gold is a soft metal, of a beautiful yellow color. Its unchangeableness on exposure to air, its beautiful color, its splendid metallic lustre, and its high specific gravity, have caused it to be regarded as the king of metals. The alchemists represented it by the circle ☉, which is also the emblem of perfection, and called it Sol, or the sun. It surpasses all metals in malleability; this is well illustrated by the fact, that thirty ordinary-sized gilt buttons are covered by a single grain of gold. It is also so ductile, that one grain may be drawn into a wire 500 feet in length. The process of wire-drawing is very simple; it consists in drawing rods of metal through a succession of trumpet-shaped holes in a steel-plate, each being a little smaller than its predecessor, until the requisite degree of fineness is obtained. As the metal, in this process, is liable to become hard and to break, the metal intended

for wire is previously made to undergo the operation of *annealing*, which is accomplished by heating it to redness and allowing it to cool slowly, by which means its toughness is greatly increased.

Gold, in consequence of its softness, is not very durable: for coin, and for elaborate articles of jewellery, it is therefore always *alloyed* with silver or copper. All the gold at present coined is alloyed only with copper; previous to the year 1826, the alloy likewise contained silver—hence the paler colour of that coinage. Our English sovereigns and half-sovereigns contain one-twelfth of their weight of copper.

Gold-leaf is made by rolling out plates of pure gold as thin as possible, and then beating them between folds of membrane with a heavy hammer, until the requisite degree of tenuity has been obtained. Its thickness amounts to only $\frac{1}{252000}$ of an inch. The gold leaf is made to adhere to the wood of picture-frames, or other surfaces, by means of size or varnish.

The modern process of *electro-gilding* is effected by dipping the articles into a solution of gold (obtained by dissolving oxide of gold in a watery solution of, so-called, cyanide of potassium), into which the poles of a battery are introduced.

2. SILVER. Latin, ARGENTUM. Symbol, Ag. Sp: gr: 10·5. Equivalent, 108.

As gold was compared by the alchemists to the sun, silver became the emblem of the pale “silvery” moon, under the name of Luna, or Diana; symbol, ☾. It is found in the native state, and in combination with sulphur, as sulphuret of silver.

The ores are deposited in veins in mountains, and contain the metal united with others, especially lead. It is never found, like gold, in the sand and alluvial soils washed down by streams.

Native silver crystallizes in cubes (like dice) and octahedrons; but it is more commonly found in irregular masses. In 1478, a rich vein of silver-ore was discovered at Schneeberg, in Saxony, and so large a mass of native metal was cut out, that it served as a dining-table to Duke Albert. When smelted, it yielded 44,000 lbs. of metal.

Silver-ore, properly so called, is not common in England; but our lead-ores often contain much of the metal.

On the continent, the mines of Schemnitz, in Hungary, are very productive. Every hundred-weight of the ore, consisting of masses of quartz, filling a vein which traverses a clay-slate, yields about five ounces of silver. At Kremnitz, mines of gold and silver have been worked for a thousand years.

The Bohemian mines furnish about 2000 ounces annually.

Sweden and Norway also possess fertile mines. At Kongsberg, in Norway, the mines yield very considerably, and average annually about 5000 lbs. weight of silver.

The most important mines in Asia, those of Kolyvan, in the Altai mountains, have produced as much as one-and-a-half million of pounds weight in the last hundred years.

But South America is the country for silver. The mines of Potosi have been long celebrated. These mines are in a mountain of that name, near the source of the River Plata (Silver), which derived its name from this circumstance. This mountain, which, in the form of a sugar-loaf, rises to a height of 4,200 feet, is filled with silver-ore, and the whole mountain is perforated, in every direction, for its gain. It was opened in 1545, and since that time its produce has been valued at 235 millions sterling! The Mexican mines are now the most productive: the most famous of them is the mine of Valenciana. Suffice it to say, that the silver mines of America yield annually about £7,250,000 sterling.

The chief part of the silver of commerce is obtained by the process of amalgamation, founded on the easy solubility of silver and other metals in quicksilver. The fluid amalgam, which is easily

separated from the mud of the ore by subsidence and washing, is strained through a strong linen cloth, and the solid portion exposed to heat in an arrangement by which the mercury is volatilized and collected, separate from the silver, which is left behind in a more or less pure state, according to the nature of the ore.

A very large quantity of silver is obtained from some native ores of lead. For the purpose of obtaining the silver from this description of ore, the lead is re-melted, and allowed slowly to cool. The portion which first crystallizes is nearly pure lead; the alloy of silver, being more fusible than lead itself, is drained off, and found to contain all the silver. The further process depends upon the fact that lead oxydizes easily, whilst silver has no such tendency. And in this lies the difference between *noble* and *base* metals. The former not only do not easily oxydize, but, on application of heat, their oxides part with oxygen, and are reduced to the metallic state. The opposite is the case with the base metals; they easily oxydize, *tarnish*, or *rust*. When, therefore, this silver-lead is exposed to a red-heat on the shallow hearth of a furnace, while a stream of air is allowed to play upon its surface, the lead rapidly oxydizes, and the oxide is constantly swept away by the blast. When the chief part of the lead has been thus removed, the residuum is placed in a shallow dish made of bone-

ashes, and again heated. The last of the lead is now removed; it becomes oxydized, and sinks into the bone-ash, while the pure silver remains behind, exhibiting all its native brilliancy.

Pure silver is the whitest of all metals; it has considerable brilliancy, and takes a high polish. It is harder than gold, and melts at about 1832° F., but does not oxydize. It resists the action of air and water: the tarnishing of silver is due to sulphur, and not to oxygen. It is highly malleable and ductile, and may be extended into leaves not exceeding $\frac{1}{10000}$ of an inch in thickness, and drawn into wire far finer than human hair.

Silver plate and coin are formed of an alloy of silver with copper. By the addition of a small quantity of copper, silver becomes harder, while its whiteness is scarcely impaired. The standard silver of England contains, in 12 parts, $11\frac{1}{10}$ of pure silver, and $\frac{9}{10}$ of copper. When such silver is heated to redness in the air, it blackens, from the formation of black oxide of copper; if this be removed by immersion in hot dilute sulphuric acid, a film of pure silver, called *blanched* or *dead silver*, remains. The blanks for coins are treated thus before they are struck, whence the *whiteness* of new coin.

The better kind of *plating* is performed by the application of a plate of silver to the surface of the copper, which is afterwards beaten or drawn out.

Electro-plating is now very generally employed. The beauty of the metal, and its freedom from injury by the air, render it well adapted for ordinary purposes, and it is now frequently used for the inside of saucepans; it should, however, be kept clean, all contact with acids being avoided.

Whilst on the subject of silver, it may be mentioned that one of its salts, *nitrate of silver*, is a component part of *marking-ink*. Silver is easily soluble in nitric acid, and forms a perfectly clear and colorless solution. By exposure to light, it is again partially reduced to the metallic state, and minute particles of silver, in form of a fine black powder, separate. It is very caustic, and easily destroys both skin and flesh when concentrated. Indeed, such a solution of nitrate of silver, evaporated to dryness, fused, and cast in small cylinders, forms the *lunar caustic* of medicine. It is employed by surgeons for cauterizing, or burning away the diseased flesh in wounds. Indelible or marking ink is but a solution of lunar caustic, or nitrate of silver, in water, blackened by Indian ink, and thickened by gum arabic. Nitrate of silver is likewise one of the ingredients of hair-dyes.

A most dangerous explosive compound, called *fulminating powder*, is a salt of silver.

The use of silver in photographic and calotype purposes need but be mentioned.

3. QUICKSILVER or MERCURY. Latin, HYDRARGYRUM. Symbol Hg. Sp: gr: 13·56. Equivalent, 202.

This metal is not only of great importance in medicine and in the arts, but is the only example we possess of a metal fluid at the temperature of most climates. Its silver-white color and its fluid property gave rise to its name; the word Hydrargyrum being derived from the Greek ὑδωρ, hudor, *water*, and ἀργυρος, arguros, *silver*.

It has been known from very remote ages. Combined chemically with sulphur, as *sulphuret of mercury*, *cinnabar*, or *vermilion*, it is found in considerable quantities. The principal mines of mercury are in Peru, in South America; in China; and in Spain: but the most celebrated are those at Idria, in Carniola. The metallic vein is situated at a depth of 720 feet. The mineral products of this mine are so varied, that the modes of carrying on operations differ from any other. In some parts pure mercury distils in globules from the rock! The ore is raised in square boxes, by means of a water-wheel, and besides metallic mercury obtained from the ore by distillation, all the preparations of mercury, used in medicine and the arts, are either found naturally, or manufactured at Idria. From the great heat of the mines, and the unwholesome vapor of the metal, the miners suffer severely. They

soon lose their teeth from salivation, and few survive forty years of age. Cattle cannot be reared, and neither fruit nor grain will ripen in the neighbourhood. The inhabitants of the town are fearfully afflicted with toothache. The miners become so impregnated with mercury, that a piece of brass, rubbed between the fingers, becomes white like silver. The process of obtaining this metal from its ordinary ore, the sulphuret, is dependent upon the removal of its sulphur. One method is to heat it with a metal which has a strong affinity or attraction for the sulphur with which the quicksilver is combined. Thus, if cinnabar be heated with iron-filings in an iron retort, the mercury will distil over, and the iron, combined with the sulphur, remain as sulphuret of iron in the retort.

In Spain another method is employed. The sulphuret is reduced in a peculiar furnace without any addition, simply by bringing the flame into contact with the hot ore; the sulphur unites with oxygen and forms sulphurous acid gas, whilst the quicksilver is separated in the metallic state, because, being a noble metal, it has no tendency to become oxydized.

Pure quicksilver is a white, silvery, lustrous fluid, without taste and smell. The metal volatilizes sensibly at all temperatures above 70°, and boils at 670°, at which it may be easily purified from all fixed impurities. At 40° below zero, it is

malleable, great contraction taking place in the act of solidification. At common temperatures it is quite unchangeable in air; but if adulterated with tin or lead, loses not only much of its fluidity, but also tarnishes easily. On account of its mobile, restless character, the name of the heathen god *Mercury* was given to it; and, even now-a-days, the term mercurial, applied to an individual, has not lost its meaning. .

Alloys of mercury, with other metals, are termed *amalgams*. The property of forming such amalgams with gold and silver, has been already noticed. Next to its *medicinal* properties, quicksilver is most important for silvering looking-glasses; this is accomplished by an amalgam of tin. The process is briefly this:—A perfect sheet of tinfoil, somewhat larger than the plate-glass, is placed upon an even table of slate or stone: quicksilver is then poured upon it, and rubbed upon its surface by a hare's foot, or a ball of flannel or cotton, so as to form a clean and bright amalgam. Upon this, excess of mercury is poured till the metal has a tendency to run off; the plate of glass, previously made quite clean, is then brought horizontally towards the table, and its edge so adjusted, as by gradually and steadily sliding it forward, to displace some of the excess of mercury, and float the plate, as it were, over the amalgam, the dross upon its surface being pushed on by the edge of the glass, so that the mer-

cury appears beneath it with a perfectly uniform, clean, and brilliant reflecting surface. A number of square weights, of 10 or 12 lbs. each, are now placed side by side upon the surface of the plate, so as entirely to cover it, and press it down upon the amalgamated surface of the tin: in this way the excess of mercury is partly squeezed out, and the amalgam is made to adhere firmly to the glass. The mercury, as it runs off, is received into a channel on the side of the table, which is slightly inclined to facilitate the draining, and in about forty-eight hours the weights are taken off, and the plate is carefully lifted from the table and set nearly upright, by which the adhering mercury gradually drains off, and the solid crystalline amalgam remains perfectly and uniformly adhering to the glass." (Brande.)

Amalgams of silver, and of another metal, cadmium, are used for *stopping* decayed teeth.

Cinnabar or *vermilion*, is a compound of sulphur with mercury: its symbol is Hg S^2 . Of all the manufacturers of vermilion, the Dutch are the most successful; the best is therefore obtained from Holland. It is not only valuable in painting, but is very extensively used in making sealing-wax.

Calomel and *corrosive sublimate* are chlorides of mercury, that is to say, composed of chlorine with mercury. The latter is a fearful poison, for which white of egg is the best antidote.

A *fulminating* powder, analogous to that from silver and gold, is also prepared from mercury. It is used extensively in the manufacture of percussion-caps.

4. ZINC. Latin, ZINCUM. Symb. Zn. Sp: gr: about 7. Equivalent, 32.

This metal is tolerably abundant, and very useful. It is so very slowly acted upon by the air, that it is now most frequently employed for coating iron for the prevention of rust, and is used for roofing, gutters, chimney-tops, &c. In China and India zinc has been long known; and utensils of zinc, inlaid with various metals, are not uncommon in those countries.

Zinc does not occur in the native state. It is found in combination with sulphur, as *sulphuret of zinc*, Zn S ; or in the more valuable form of *carbonate of zinc*, or *calamine*, $\text{Zn O} + \text{CO}^2$. The latter is preferred for the extraction of the metal. It is first roasted, to drive off water and carbonic acid, and thus an *oxide of zinc* is formed. The metal is obtained from the latter, by heating it in clay pots or crucibles, with small pieces of coke or charcoal. At a full red heat carbonic acid escapes, and the metal drops through a hole in the bottom of each pot, by an iron tube, into a vessel of water. By simple roasting the sulphur may be driven off

from the sulphuret in form of gaseous sulphurous acid.

Zinc, obtained from either of these sources, is a blueish white metal, and at ordinary temperatures rather brittle. Between 250° and 300° it is, however, malleable, and may be rolled or hammered into sheets, which retain their malleability when cold. It melts at 773° , and volatilizes at a red-heat.

In commerce, zinc is known by the name of *Spelter*, and its ore, the sulphuret, as *Blende* or *Black-jack*. The largest supplies come from Silesia.

Among other important purposes, zinc is employed in the construction of *voltaic batteries*, used for evolving electricity by chemical action; and also in making a most valuable paint.

5. LEAD. Latin, PLUMBUM. Symb. Pb. Sp: gr: 11.35. Equivalent, 104.

Next to iron, *Lead* is the most abundantly diffused of the household metals. Like zinc, it is but slowly acted upon by the air, and owing to its malleability is especially adapted for covering roofs.

The most important ore of lead is the *sulphuret*, commonly called *galena*. In lustre the ore resembles the pure metal, but it is brittle, and requires a white heat for fusion. It occurs massive, and beautifully crystallised in form of cubes.

In our own country, lead is one of our most im-

portant and abundant metallic productions. There are mines in Derbyshire, Cornwall, Devonshire, and other counties; also in Wales, Scotland, and Ireland: *sulphuret of lead*, Pb S , is the common ore of them all.

It has been already spoken of, as often containing silver, and the mode of separating the silver from it has been described. The process for obtaining lead from its ore is very simple. The mixed ore having been broken and washed, is roasted in a reverberatory* furnace, the temperature being such as to soften, but not fuse it. By this process part of the sulphuret becomes oxydised, and converted into sulphate of lead; much, however, remains unaltered. Now, it is known to chemists, that, when sulphate and sulphuret of lead are heated together, they re-act upon one another, and produce sulphurous acid gas and metallic lead. The contents of the furnace are therefore thoroughly raked together, and the temperature increased; the melted lead sinks to the bottom, and is run out into oblong moulds called *pigs*.

The mines of Great Britain furnish upwards of 50,000 tons of smelted lead annually.

* *Reverberatory furnaces* are much used when substances are to be exposed to heat without contact with the fuel. The fire-chamber is separated from the hearth by a low bridge of brick-work, and the flame and heated air are reflected downwards by the arched form of the roof. Great heat is obtainable from such a furnace.

Pure lead is a blueish-white metal. It is very soft, and, when fresh cut, has much brilliancy. It melts at 612° , and is then, by the action of the air, easily convertible into an oxide. It may be cast, without trouble, into a variety of useful forms.

The surface of lead readily tarnishes, and is easily acted upon by soft water. Although a slow, it is a most fearful poison. Its salts have a sweet taste, so that in a dilute state it gives no unpleasant warning of its presence. Fortunately, most waters contain gypsum, the sulphuric acid of which forms an insoluble salt with the oxide of lead. Thus spring waters may be kept with impunity in cisterns of lead, provided the covers be of wood. Otherwise, the pure water which evaporates and settles in drops upon the lid, is liable to dissolve it in small quantities; and thus poisonous properties are communicated to the water.

The alchymists gave this metal the name and symbol of *Saturn*, h .

Some of the oxides and salts of lead are very important. *Red Oxide of Lead*, *Minium*, or *Red Lead*, is used as paint, as well as in the glass-manufacture. It is a tasteless, insoluble, scarlet powder, and contains more oxygen than common litharge, as may be readily perceived from the formula of the two compounds: Litharge is Pb O ; Red Lead Pb O^4 . *White Lead*, which constitutes the basis of most paints, is a *carbonate of lead*. The white lead

of commerce is prepared by placing sheets of lead* over earthen pots, containing a few ounces of crude vinegar. The pots are kept surrounded by spent tan, and closely covered. After some time, the lead is found to be in great part converted into white lead, the carbonic acid of which has been evolved from the tan. *Chromate of lead* is a beautiful yellow pigment, much used in calico-printing, and in painting coach-panels. *Goulard's Lotion* is a salt of lead.

Type-metal is an alloy of 130 parts of lead, with 8 of a metal called antimony.

6. TIN. Latin, STANNUM. Symbol Sn. Sp: gr: 7·285. Equivalent, 59.

This metal has been known from the earliest ages. Pliny relates that the Phœnicians traded with Britain and Spain for tin. It still occurs most abundantly in Cornwall; and is found in considerable quantities in Malacca, India, and Germany.

The principal ore of tin is the native oxide, Sn O^2 ; but it likewise, though more rarely, occurs as a sulphuret. The oxide, or tin-stone of Cornwall, is

* The lead should be of the purest. If it contain iron, the resulting white lead acquires a tawny hue; and if a trace of silver, it becomes dingy on exposure to light. Derbyshire lead-ore contains traces of cobalt; white lead made therefrom has usually a pinkish hue in consequence.

known by the names *mine-tin* and *stream-tin*, according to the source from whence it is obtained.

The principal tin-mines of Cornwall are in the neighbourhood of St. Austle and the Land's End, and the mode practised there of reducing the ore is briefly as follows. The ore is pounded, or *stamped*, on the spot, in the stamping-mill, which consists of heavy beams of wood, shod with masses of iron, weighing $1\frac{1}{2}$ cwt. each. These beams are raised by means of water-wheels, and fall by their weight on the ore, which is placed in troughs, through which a small stream of water runs, in order to wash away the ore as it is pounded fine. One end of the trough is formed of iron plates pierced with holes, through which the ore is sifted, as it were, and passes into other troughs or pits, in which it settles from the water in various degrees of fineness.

The ore thus pounded is washed in vats called *keeves*, to free it from all soluble earthy matter and dirt, previous to its being smelted.

It is then roasted, to remove the sulphur and arsenic, with which it is always contaminated. Mixed with charcoal and a little lime, it is heated in a reverberatory furnace for eight hours; the charcoal combines with the oxygen of the oxide of tin, in the form of carbonic acid, while the lime, uniting with the silica and other impurities, forms slag. The impure tin thus obtained is again returned to the furnace, and carefully heated, so as to melt the tin,

which runs off into an iron kettle, while the chief impurities remain unmelted. The tin in the kettle is kept in a state of fusion, and agitated by plunging into it wet charcoal, which causes the impurities to rise to the surface, where they are skimmed off. Thus refined, the metal is cast into blocks, of 3 cwt. each, called *pigs*.

The tin which is obtained from the ore washed down by *streams*, is purer and more free from arsenic than that from the veins. The largest *stream-tin* works are at Carnon, near Redruth.

The purest kind of tin is sold under the name of *grain-tin*: *block-tin* is less pure.

The pure metal has a white color, and emits a peculiar crackling noise when twisted. Its taste and odor are disagreeable. It is very malleable, as may be inferred from the fact, that tin-foil is less than $\frac{1}{1000}$ of an inch in thickness. It melts at 442° , and may then be easily crystallized. Heated above its melting point, it oxidizes rapidly, and is converted into *putty-powder*, or *tin-putty*, a whitish substance used for polishing. By itself, the oxide is infusible; melted with glass, it forms *white enamel*.

Sulphur unites with tin, and forms a compound possessed of extraordinary golden lustre. *Mosaic gold*, or *musive gold*, is a bi-sulphuret of tin. It is much used, especially by paper manufacturers, under the name of *bronze powder*. Its symbol is Sn S².

Some of the alloys of tin are important. *Pewter*

is usually compounded of 20 parts of tin with one of lead, or another metal, bismuth. *Tin-plate* is another most useful alloy. Iron-plate and kitchen utensils may be coated superficially with tin, and thus preserved from rusting away. The only objection is, that the iron, if anywhere exposed, has an increased liability to oxidize, or rust. This is especially the case with tin-plate; hence the superiority of iron-plate coated with zinc instead of tin.

7. COPPER. Latin, CUPRUM. Symbol, Cu. Sp: gr: 8·86. Equivalent, 32.

Its name is derived from the island of Cyprus, where this metal was first wrought by the Greeks. The brass of the ancients, of which they made their implements, both of agriculture and of war, was an alloy of tin and copper. The alchemists called copper, Venus ♀, the name of the protecting goddess of Cyprus.

It sometimes, but rarely, occurs in the metallic state. The most important ore, and that from which the metal is chiefly obtained, is the *yellow copper ore*, or *copper-pyrites* (from the Greek πῦρ, pyr, fire). It is a compound of one part of sulphuret of copper with one of per-sulphuret of iron, and is represented chemically by the formula $= \text{Fe}^2 \text{S}^3 + \text{Cu}^2 \text{S}$. It is of a brass yellow color, and of the hardness of fluor-spar. There are mines in An-

glesea and Cumberland, but the most extensive and the richest are those of Cornwall and Devonshire. The principal mines lie between the Land's End and Truro, the most important being in the neighbourhood of Redruth.

There are upwards of eighty copper-mines in Cornwall, varying in their productiveness from 100 to 1500 tons of copper annually.

Besides those of England, copper-mines are worked in Spain, Saxony, Sweden, Norway, Russia, and Mexico. The principal copper-mine in Sweden is the celebrated one of Fahlun, in the province of Dalecarlia. This mine is a vast chasm, formed by the artificial excavations for the ore, the bed of which is not a mile in extent.

The process of reduction is carried on most largely in South Wales. There the ore is first roasted, by which the sulphuret of iron is oxidized, while the sulphuret of copper remains unaltered. The roasted ore is then strongly heated with sand, which combines with the oxide of iron, forming a fusible slag, which separates from the heavy sulphuret of copper. By a repetition of this process the iron is got rid of, and then the sulphuret of copper begins to decompose in the reverberatory furnace, losing its sulphur and absorbing oxygen. The temperature of the furnace is then raised, and the oxide of copper reduced to the metallic state by the aid of charcoal. The last part of the process consists in

thrusting into the melted metal a pole of birchwood, the object of which is to reduce a little remaining oxide by the combustible gases thus generated. (Fownes.)

With one single exception, copper is the only metal which has a red color. It is very lustrous, very malleable and ductile; indeed next so in degree after gold and silver. Like tin, it emits a smell when rubbed with a moist hand. Its melting-point has been fixed between that of silver and gold, and is placed by Daniel at 1996°.

Copper is a most useful metal, and many valuable household utensils are formed from it. It is, too, the most sonorous of all metals, and is therefore employed for trumpets, and similar musical instruments. Unfortunately it tarnishes, or oxidizes, easily.

One of the two oxides of copper is possessed of a beautiful red color, which may be easily prepared artificially. Copper vessels, such as tea-urns, are often coated with this sub-oxide.

All the salts of copper are poisonous. Thus we find that when a copper vessel is exposed to moist air it becomes covered with so-called verdigris. The green crust thus formed is a carbonate of copper. It is prepared as a pigment, under the name of green verditer. *Malachite*, which is found in much beauty in the Ural mountains of Siberia, and in Australia, and made into ornaments, is a

native carbonate of copper. *Sulphate of copper*, or *blue vitriol*, is of a sapphire-blue color. It is much used in the arts as a source of several blue and green colors; and a solution of it is employed in electrotyping. *Verdigris*, $\text{Cu O}, \bar{\text{A}} + \text{HO}$, a salt of a green or blue color, is a combination of acetic acid with oxide of copper. It is a beautiful pigment, but a fearful poison. Care should be taken to keep vinegar from all copper vessels, which should be kept at all times scrupulously clean.

The alloys of copper are very important. Thus *brass* is an alloy of copper and zinc. The proportions vary, and some contain a little lead and tin. *Pins* are usually made of brass and coated with tin. The famous *Corinthian brass* was an alloy of copper. Pliny states, that vases made of this brass were considered more valuable than if made of gold, on account of its beauty. The cutting instruments of the ancients were alloys of copper with five per cent. of tin. *Tombac*, *Pinchbeck*, *Dutch-gold*, and *Similar*, are alloys of brass with copper. *Bell metal* is an alloy of copper and tin; so likewise is *Bronze*. *Speculum metal* contains, in addition to copper and tin, a little arsenic. Whilst on the subject of alloys of copper, may be mentioned the existence of a beautiful metal called NICKEL. It is found in the Hartz mountains, and in some few other localities. It is a white, malleable metal, fusible with difficulty, and strongly magnetic. Its chief use is in the pre-

paration of several beautifully white alloys, some of which are only inferior to silver. *German silver* is an alloy of 100 parts of copper, 60 of zinc, and 40 of nickel. *China silver* or *tutenag*, *Britannia metal* and *Argentine*, of which forks, spoons, tea-pots, &c. are made, are alloys in various proportions of copper, zinc, and nickel. (Such spoons and forks should not be allowed to remain in contact with pickles or any acid sauces.)

8. IRON. Latin, FERRUM. Symbol, Fe. Sp: gr: 7·8.
Equivalent, 28.

Is the most important of all metals. It has not, indeed, the beauty of color, nor the fineness of quality which gold and silver possess. But the grand difference between iron and other metals is its hardness, and its capability, by a peculiar process, of being made into *steel*, which is so hard that it can cut every substance in nature, with the exception of the diamond. It is universally diffused over the earth, and there is no soil that does not contain more or less of the oxide of this metal. Iron has been known and employed by man from the earliest ages of his existence, knives and arms of iron being mentioned in the Book of Moses. The name and symbol of Mars, ♂, the god of war, was given to it by the alchemists.

Native iron is found in small quantities in the

Ural mines. Those immense masses of metal, known as meteoric, are usually termed native iron. But the source from whence the quantities for the world's supply are drawn, is not from native iron, but chiefly from its oxides and carbonates.

The *magnetic iron ore*, or *loadstone*, is black and lustrous; and sufficiently magnetic to take up a needle. It is abundant at Roslagen, in Sweden, and is manufactured into a kind of bar-iron, from which the best steel is made.

It is more readily fusible than iron, and is of an iron-black color. It is a chemical compound of the two chief oxides of iron, and is, in fact, composed of one equivalent of each oxide.

It consists, in 100 parts, of—

Protoxide of iron,	31·00
Peroxide of iron	69·00
	<hr/>
	100·00

Loadstone is therefore represented by the formula $\text{Fe O} + \text{Fe}^2 \text{O}^2$.

Red-iron-stone, or *hæmatite*, abounds near Ulverstone, in Lancashire. From it, some of the best iron-plate and wire are made. It is of a brown-black or ochreous color. It is a true *peroxide*, or red-oxide, or sesqui-oxide of iron—for it is known by all these names. When pure, it consists, in 100·00 parts, of—

Iron	69·23
Oxygen	30·77
	<hr/>
	100·00

Its symbol is therefore $\text{Fe}^2 \text{O}^3$.

There are also several varieties of the *hydrated hæmatite*, which is represented by the formula :
 $3 \text{HO} + 2 \text{Fe}^2 \text{O}^3$.

Clay-iron-stone, so called on account of the large admixture of clay with the oxide of iron, is likewise abundant. But the coal formations of Staffordshire, South Wales, and Scotland, from whence the great supply of British iron is obtained, consist of carbonates of the protoxide of iron. Proto-carbonate of iron, when pure, consists, in 100 parts, of—

Protoxide of iron	62
Carbonic acid	38
	<hr/>
	100

Its formula is therefore $\text{Fe O} + \text{CO}^2$.

It must not, however, be supposed that our iron is made from a pure carbonate. Clay-iron-stone is a mixture, as the following analysis of a Scotch ore proves :—

Protoxide of iron	45·84
Carbonic acid	33·63
Lime	1·80
Magnesia	5·70
Silica	7·75
Alumina	2·43
Coal	1·83
Water	1·02
	<hr/>
	100·00

The process of the manufacture of the metal is not difficult to be understood. The clay-iron-stone is first *roasted* with coal, by which the carbonic acid is removed from the carbonate, and the metal remains in combination with oxygen, as red oxide of iron. It is now ready to be *smelted*. This process is conducted in the so-called blast furnace, a tall building 50 or 60 feet high. Into this blast furnace a mixture of equal weights of roasted ore and coal, with one-fifth of limestone, is thrown, and powerfully heated by means of a current of air, introduced at the bottom. The carbon of coal enters into combination with the oxygen of the ore, and forms carbonic acid, which escapes in the form of gas. The lime unites with the silica of the ore, and with other impurities, and forms a slag, which, being lighter than the metal, swims on the surface. In the course of a day and night the iron is found in metallic shape, and is drawn off by taking out a plug made of clay, inserted at the bottom of the furnace. It is allowed to run into a bed of sand, which is formed into channels and furrows. Iron *cast* in these channels of sand is called *pig-iron*. Such iron is combined chemically with carbon.

Wrought-iron is made from cast-iron by the process of decarbonizing. The removal of a portion of this carbon, or the *puddling process*, is effected by introducing the metal into a reverberatory furnace; after being powerfully heated and stirred for a few

hours, it is made into balls, which are hammered, and drawn between rollers, while still hot, into bars.

Iron is a metal of a blue-white color, fusible at a white-heat. It is very ductile, but cannot be hammered out into very thin leaves, as it becomes pasty before it melts. It admits of being welded, or joined by hammering, to other pieces of red-hot metal. When exposed to damp air it rusts, *i.e.* unites with oxygen, and forms red oxide of iron. By contact with lime, potash, or soda, iron may be preserved from corrosion, as also, to some extent, by contact with zinc: hence the advantage of coating iron with zinc.

Steel is prepared by heating iron in contact with charcoal. Bars of Swedish iron are embedded in charcoal-powder, contained in a crucible capable of resisting heat, and exposed for hours to a bright red-heat. The iron takes up about $1\frac{1}{2}$ per cent. of carbon, and becomes harder. The product is called *blistered* steel, from the appearance of the bars. The texture is improved by welding a number of these bars together, and drawing the whole out under a light tilt-hammer. The most wonderful property of steel is that of becoming very hard when suddenly cooled. If a piece of steel be heated to redness, and then plunged into cold water, it becomes capable of scratching glass. If re-heated, and allowed to cool slowly, it again becomes as soft as ordinary iron. The articles forged into shape are

first hardened in the manner described; they are then *tempered*, or *let down*, by exposure to a proper degree of annealing heat, which is often judged of by the color of the thin film of oxide, which appears on the polished surface. Thus, a temperature of about 430° F., indicated by a faint straw-color, gives the proper temper for razors; that for scissors, pen-knives, &c., will be comprised between 470° and 490°, and be attended by a full yellow or brown tint. Swords and watch-springs require to be softer and more elastic, and must be heated to 550° or 560°, or until the surface becomes deep blue. Attention to these colors has now become of less importance, as metal baths are often substituted for the open fire in this operation. (Fownes.)

To all the valuable qualities of iron that have been mentioned, must be added its usefulness as a medicine. Many springs derive their name from the iron contained in them. Chalybs is the Latin for steel; hence the derivation of *chalybeate*. There are very few waters that do not contain traces of iron; indeed I cannot say that, of the many waters which I have analyzed, I have ever found any entirely without it. A quantity of bi-carbonate of iron, $\text{Fe O} + 2 \text{CO}^2$, the form in which it is usually contained in water, not exceeding one-fifth of a grain in a gallon, is sufficient to give it a decided taste. When waters contain much of it, they give positive signs of its presence, by leaving a yellowish-red stain of ochre on the soil over which they pass;

for not only is carbonate of iron insoluble in water containing no carbonic acid, but its tendency to attract oxygen is so great, that when once it comes in contact with air, it, by its conversion into a higher state of oxidation, entirely loses its solubility. Iron-ochre is, therefore, a higher grade of oxidation than that we meet with in clay-iron-stone, or in solution in chalybeate waters. When iron is exposed to the atmosphere, it *rusts*, and becomes covered with the red oxide or ochre.

Some of the salts of iron are of immense importance. *Green vitriol*, sulphate of iron, or *copperas*, is prepared commercially on a large scale in the alum manufacture, the sulphate of iron being crystallized out of the sulphate of alumina. The *potash-tartrate of iron*, so much used as a tonic in medicine, is obtained by boiling the red oxide with cream of tartar. *Prussian-blue*, the fine blue color used for dyeing woollen dresses, is a salt of iron. It is used by washerwomen, under the name of *blue*, to hide the yellow color of linen. Even the ordinary *writing-ink* is a salt of iron. There exists in nut-galls, in oak-bark, in fact in many trees, a substance called *tannin* or *tannic acid*, which possesses the property of precipitating glue from its solutions, as *tannogelatine* or *leather*. The *tannate of red oxide of iron*, or *ink*, is prepared by adding tannic acid to a salt of iron, in a manner which will be described in the supplementary chapter on experiments.

In fact, iron is of universal occurrence. It is to

be found in leaves, fruits, stalks, stems, and flowers; in every mineral; in the flesh and blood of men and animals; and even in milk and water. And as an agent of civilization it ranks so high, that it may be safely called the most important of all metals.

QUESTIONS ON CHAPTER VIII.

Where is the grand store-house of the metals? How are they usually found? How many metals are known to chemists?

What are the principal features of the metals?

How do we determine specific gravity?

Do the metals vary much in point of color?

Do they differ widely as to fusibility? Recite what you know.

Are the metals capable of assuming all the three forms of matter? Do you know an instance?

What is the difference between malleability and ductility?

Do mining operations differ much?

What do we mean by crystallization? Is the cause of it known?

What is the Latin name for *gold*? What is its specific gravity? Its symbol? Its equivalent?

Are traces of the metal commonly met with? Is it ever found otherwise than native?

Is it ever found in the United Kingdom? Name some places. Why is it not worked in Ireland?

How do the negroes obtain it in Africa?

Do we obtain much gold from Russia?

Did Columbus meet with it in Hispaniola? Who had large presents of gold made to him at the conquest of Mexico? Who discovered the celebrated Potōsi mine? Relate the story? Is it alone famed for gold? Is gold found

in the Brazils? Give an instance of the accursed lust of gold. What is the appearance of the river in which the gold was found?

Who first suggested that gold might be found in Australia? Who discovered it there? In what part was it first found?

In what kind of soil was it found? Were any further discoveries made? Relate what you know.

What is the nature of the soil in which the gold is usually found? At what depth?

How is the gold separated from the dross?

When gold is embedded in stone, what process is employed?

What kind of a metal is gold? Why was it called king of metals? Why is the sun its symbol? Is it malleable? Is it ductile? Give an instance? How is the art of wire-drawing accomplished?

What is gold usually alloyed with? Why so? How much copper do our coins contain?

How is gold-leaf made? What is its thickness?

By what Latin name is *silver* known? What is its specific gravity? Its symbol? Equivalent?

What name did the alchemists give to silver? Why? Is it found native? Ever otherwise? How are the ores found? Is it ever found like gold?

How is native silver usually found? Relate what you know of the piece found at Schneeberg in Saxony?

Do the lead-ores of England contain silver?

What do you know of Hungary as a source of silver? Where is it found? How much does it yield?

How much silver do the Norwegian mines yield?

Which are the most important Asiatic mines? How much have they afforded in the last hundred years?

Which is the chief country for silver? Which are the most celebrated mines? What is the name of the mountain? Describe it? Why is the river La Plata so called? How much silver do all the mines of South America yield annually?

How is the silver of commerce obtained by amalgamation?

Is much obtained from lead-ores? How? What is the theory of the plan? What distinguishes base from noble metals?

What is the character of pure silver? Is it as hard as gold? At what temperature does it melt? To what is the tarnishing of silver due? Is it malleable and ductile? How do you know it is the latter?

What metal is usually alloyed with silver? How much alloy is there in our silver coin? How is the blanching of silver coin performed?

What are the two chief kinds of plating?

What salt of silver is contained in marking-ink? How is it formed? What are its properties? What is it employed for by surgeons? Does it serve any other purpose?

By what common name is the explosive salt of silver known?

What is the Latin name for *quicksilver*? What is its specific gravity? Its equivalent?

Has quicksilver much value in the arts, and in medicine? What is the name hydrargyrum derived from? How is it usually found? Where are the principal mines? Relate what you know of the one at Idria? Does it injure health? How is the metal obtained?

What plan is resorted to in Spain?

What kind of metal is quicksilver? At what temperature does it begin to fly off in vapor? At what degree does it boil? At what temperature is it solid?

What is the name of an alloy of mercury? What is quicksilver used for in the arts? How are looking-glasses made?

What is vermilion? What people make it best? What is it used for?

What is calomel? Is corrosive sublimate a poison? What is the best antidote?

Is fulminating mercury of much use?

What is the Latin name of *zinc*? What is its symbol? Its specific gravity? Combining proportion?

Is zinc a useful metal? Why? Has its use long been

known? Is it ever found native? In what forms of combination is it found? How is the metal obtained from calamine? How from the sulphuret?

Describe the properties of pure zinc. What remarkable property has it?

What are the commercial names of zinc and its ores?

Is zinc employed in the arts and manufactures?

What is the Latin name of *lead*? Its specific gravity? Equivalent?

Is it abundant? What is the character of its ore? Where is it found? What is the common name of its ore? What is its composition? How is lead obtained from its ore?

How much lead is obtained from the mines of Great Britain?

What is the character of the metal?

Are its salts poisonous? Why is not water poisoned by being kept in lead cisterns?

What name did the alchemists give to lead?

Are the salts of lead important? Name some of them. How is white lead manufactured?

What is the Latin name of *tin*? Its specific gravity? Equivalent?

Where is the metal found? What is the principal ore of tin? What process is adopted for obtaining the metal?

Is one kind of tin preferable to another?

What are the properties of tin?

What is musive gold? What is it used for?

Are any of the alloys of tin useful?

What is the Latin name of *copper*? What is its symbol? Specific gravity? Equivalent?

Whence is the name of copper derived?

What is the most important ore of copper? What is it composed of? Where are the chief English mines situated?

Of what nature is the process for obtaining copper?

What do you know of the properties of copper?

For what purposes is it employed?

Are the salts of copper poisonous? What is the nature of

malachite? Where is it found? What is verdigris composed of?

Are the alloys important? What is brass? What was Corinthian brass? What are pins made of? What are they coated with? What is bell-metal? What metals does German silver contain? What is Britannia metal? Why should spoons made of such an alloy not be left in pickles?

What is the Latin name for *iron*? Its specific gravity? Equivalent?

What renders iron a metal of so much importance? Has its use been long known?

Is iron ever found native?

What are the chief sources from which iron is made? What is the composition of load-stone?

Where does red iron-stone abound? What is it composed of? Does any other such compound exist?

Is clay iron-stone a pure carbonate? Is it much employed in the iron manufacture?

What is the process? What object does the roasting serve? How is the smelting performed? What is cast-iron? How is wrought-iron prepared? What do we mean by the puddling-process?

What color is iron? At what temperature is iron fusible? Why cannot it be hammered into very thin leaves?

How is steel prepared? What does it contain in addition to iron? What is the product called? How is steel tempered? Has temperature anything to do with the color of manufactured articles? What?

Is iron useful in medicine? Is it ever contained in water? As what?

Are other salts of iron important? Which?

Is iron of universal occurrence? Name some substances in which it occurs.

APPENDIX.

SUGGESTIONS FOR EXPERIMENTS.

CHEMISTRY is a science so dependent on experiment, that it may be averred that a man may spend a life-time in reading about it, without attaining to any satisfactory knowledge on the subject. We may read about the changes which the air undergoes in the processes of respiration and combustion—we may hear that a burning candle gives off water and carbonic acid—we may see a blue-bell on the solitary heath become red during a thunder-storm:—but how much more do these become facts to our minds, when we can prove these results to be constant and ever-recurring under similar circumstances. I need, therefore, offer no apology for suggesting a series of experiments on the subjects treated of in this little volume.

PART I.—EXPERIMENTS REQUIRING NO APPARATUS BEYOND WHAT IS TO BE FOUND IN EVERY HOUSE- HOLD.

1. Take a fresh candle and light it. Mark the carbonization or apparent blackening of the wick,

the melting of the tallow, its rise into the wick, the form of the flame, and the division of the wick into the part which consumes away and that which is simply soaked in tallow.

2. Move the candle quickly through the air, and note carefully the results, as regards smell, smoke, &c. Hold a dry plate immediately over the flame—carbon is deposited;—some distance above it—the plate is not soiled.

3. Try at what distance immediately above the flame it ceases to light or even charr a piece of paper.—Repeat the experiment with a lighted camphine or oil-lamp, and find out why the paper will inflame at a much greater distance from the flame than a candle not surrounded by a lamp-glass.

4. Put a handkerchief or cloth round the *bottom* of the lamp-glass, so as to exclude the air from the lighted lamp,—it will be extinguished.—Relight the lamp, close it at top instead of at bottom, and mark the extinguishing of the flame.—Take the lamp-glass, hold it over the lighted candle, and prevent the access of air from below by means of a cloth.—Admit the air below, and close the opening with a card. In all these experiments the light is put out.

5. Take a wax-end rather less than one inch in height, or an end of a taper; kindle it, and place it on a plain deal table; cover it up with the chimney-glass, and if any air should come in between the glass

and the table (which may be known by the continuance in the burning of the candle) surround it at bottom with a rag.—Admit air at bottom by slightly lifting the glass, and then kindle the light again. Vary the experiment by closing the glass at top instead of at bottom. In both cases the light will be extinguished.—Put a card lengthways into the upper part of the lamp-glass, so as to divide the opening, and let it stand upon the table over a lighted taper. It will continue to burn, because a current is produced; fresh air rushes down on one side into the glass upon the flame which it feeds, while the foul air escapes upwards on the other side of the card. And this may be proved by the following experiment. A candle that has been burning until a long wick has been obtained, is blown out. If the red-hot wick be held on one side of the opening, formed by the card and the half-circle of the chimney-glass, the vapour will be visibly drawn down: if held on the other side, the vapour will be blown into the outer air. A candle will not burn more than two or three seconds under a tumbler. Why? Because the oxygen of the air in the tumbler is consumed in the process of combustion, and flame cannot exist in its absence.

6. Hold a wine-glass a little distance above the light; in a moment it will become covered with dew in the inside. Why? Because water is always formed when a candle or lamp burns in air. It is

deposited as dew upon the glass, because the latter abstracts so much heat, that the air is no longer able to hold all the water in invisible solution. And this will be proved by a continuation of the experiment; for if you hold the glass till it becomes warm, dew is no longer deposited. The heat communicated to the air by the flame is sufficient to prevent the watery vapour arising from the combustion of the hydrogen of the tallow, oil, or gas, with the oxygen of the air, from becoming visible.

7. Remark the fact that a candle gutters in a draught, or when the wick is too long, and think of the reason. Also that some candles require snuffing. Examine the wire round the wick of one of Palmer's decimal candles.

8. To see the effect of draught (or increase of air) upon fire, use the bellows. Let a newspaper hang down to the first bar of the grate, so as to cover in every visible part of the chimney. Think why the fire burns brighter. When you see much smoke escaping from the hot coals, poke the fire, and ask yourself why the smoke disappears, or rather is no longer formed?

9. Light a thin piece of wood, and mark the effects of admission or exclusion of air. Make up a small heap of firewood in the garden, as I have described at page 48, and study the formation of charcoal.

10. Take a spoonful of brandy, *and after having*

corked the bottle, set fire to the spirit contained in the spoon. Mark the feebleness of the light, and think over the causes of the brilliancy of flame.

11. Bring an externally dry decanter filled with cold water from the well into a warm room. Breathe on a penknife, and ask yourself in both cases where the water, that bedews the decanter and the knife, comes from. You *see* your breath in winter, and on cold days in spring—why not on warm summer days? Having proved the presence of water in the air by the decanter experiment, think about dew, and try to increase your knowledge about it. Take a thermometer into the fields of a warm summer's night, when the sun is setting. Mark the lowering of the temperature among the grass, and the consequent fall of dew. Feel the leaves of trees. Pluck off a handful, lay them for half-an-hour on the gravel walk, then quickly heap them round your thermometer, and mark its fall.

12. Your knife rusts in moist air, but not in warm dry air. Verdigris, so called, forms on copper saucepans left in moist air. Why? Think on the processes of oxydation.

13. Take some milk, warm it in a cup, and add a few drops of vinegar. Throw it upon a filter of linen, and regard the curd. Shake some cream in a small medicine bottle until the butter separates.

14. Take some flour, make it into paste with water, and wash it in a fine muslin or linen cloth

in a stream of water. Examine the gluten which remains, and the starch which makes the water milky.

15. Put an egg, or egg-shells, into a basin, and pour vinegar upon them. Place the basin on the hob, and watch the results. (An egg-shell consists of carbonate of lime or chalk. The vinegar will dissolve the lime of the carbonate of lime; carbonic acid will escape with effervescence, and you will obtain a solution of acetate of lime).

16. Put a pinch of whitening (carbonate of lime), into a champagne glass, pour some vinegar upon it; and plunge a wax-end, fastened to a piece of wire, into the glass. Ask yourself why it is extinguished.

17. Throw a piece of iron into the fire. It will not melt. If you have a ladle, melt some lead in it. Try which melts most easily, a piece of white window-glass or a leaden bullet. Think about the melting-points of various metals, and in making the above experiments, remember it is as satisfactory to melt a small bullet, as a piece of the size of a cannon-ball.

18. Dissolve a few grains of hard soap in clean rain-water, and add a few drops of this solution to hard water. You will find the soap curdle. The lime of the water forms, with the fatty acids of the soap, a greasy insoluble lime-soap, while the soda of the hard soap combines with the sulphuric acid

with which the lime of the hard water is usually associated. Until, therefore, the lime is thrown down from the hard water, the soap will not begin to act as a cleansing agent.

There are other experiments which will suggest themselves to the young student, and which therefore need not be enumerated.

PART II.—EXPERIMENTS REQUIRING THE EXPENDITURE OF BUT A FEW SHILLINGS.

1. To show the carbon in various household substances. Charr pieces of bread, meat, sugar, wood, cloth, paper, or quill-pen. In all of them the presence of charcoal may be proved. Sudden heat causes the hydrogen and oxygen of a compound to unite, because the affinity of these two elements is greater for each other, than for carbon; the consequence is, that charcoal is always separated first, when a compound containing hydrogen and oxygen, in addition to carbon, is strongly heated. But this separation of carbon may be shown in a more striking manner. Take two or three lumps of white sugar, place them in a small cup, moisten them with a few drops of boiling water, and add an eighth of an ounce of oil of vitriol. The lumps will be seen to change color. Great heat is evolved, the lumps swell up to more than four times their size, and present all the appearance of porous charcoal. (Care must be taken not to handle the charcoal, until the

oil of vitriol has been removed by repeated washings with cold water.) Tea, coffee, cheese, starch, arrow-root, sago, tapioca, white of egg, in fact, every thing that is eatable, may be proved to contain carbon. The sooner, therefore, the young student loses the idea that a substance must be black which contains carbon, the better.

2. To prove that the air is a compound of gases.—Purchase a gas-jar for a shilling, (an apparatus like a stoppered bottle without a bottom, and capable of holding about a pint,) a small porcelain cup for 2d., and a common clay-pipe, with rather a long stem; half an ounce of spirits of wine, and bottle, for 4d., a two-ounce funnel 4d., and a sheet of white filtering-paper for 1d. If you put a few drops of spirits of wine into the cup, float it upon a basin of water, and if, after setting light to the alcohol, you immediately invert on it a tumbler or the gas-jar, so that the rim touch the water on all sides, you will obtain the same results, however often you may repeat the experiment. The spirits will burn but a few seconds, dew will fill the inside of the glass, the result partly of combustion, partly of simple evaporation, and the water will rise in the glass to a higher level than that in the basin, corresponding to one-fifth of the contents of the glass; the gas, then, that alone supports combustion, forms one-fifth of the bulk of the air; for if the student examine the gas that remains in the gas-jar, he will find it will not support

flame. A lighted taper, suspended by a piece of thin copper wire, plunged, by removal of the stopper, into the gas-jar, is immediately extinguished. Lime-water will prove the presence of yet another gas; for if a tumbler be half-filled with lime-water, and poured from some height, backwards and forwards, into another tumbler, the clear liquid will become clouded by a white precipitate. (Oxygen alone supports combustion, carbonic acid extinguishes flame and precipitates lime-water, and nitrogen extinguishes flame.)

3. To prove that the air changes its character by respiration, as well as by combustion.—Fill the gas-jar with water, by simply withdrawing the stopper, and plunging it into a slop-basin filled with water; when full, stopper it, and hold it so that the rim at the bottom is kept under water; now breathe the air from your lungs through the tobacco-pipe into the jar, the gas by its lightness will rise up through and displace the water; and when full, transfer the jar carefully to a cheese-plate, by immersing the plate under water, and closing the bottom of the jar with it before you place it upon the table. This part of the experiment you must perform carefully, for, if you admit air, it will fail. On immersing a lighted taper into the jar it will be extinguished. If the experiment be performed with care, the result will be constant. The oxygen of the air is removed by the blood, and in its place carbonic acid is substituted; this, too, may be easily proved. Fill the

gas-jar out of doors with ordinary air, put about half-an-ounce of lime-water into a cheese-plate, place the jar upon it, and shake the enclosed air with the lime-water; because the amount of carbonic acid in the air is comparatively very small, only a slight turbidity of the lime-water will be perceived; but if you test the air breathed out of your lungs in a similar manner, pouring in a little lime-water, instead of using a lighted taper, the lime will, by agitation, be precipitated in white flakes. I have before stated, that the use of the blow-pipe is to increase the heat of the flame; and here I would recommend the student to practise a most instructive experiment. The air employed for the blow-pipe is simply external air taken into the *mouth*, and propelled by the cheek muscles. And the difference may be strikingly exemplified, by examining the air emitted from the lungs, and that propelled simply by the mouth muscles. The air from the first extinguishes light, and strongly precipitates lime-water; in the latter the taper burns as well as in pure air, and lime-water is only slightly precipitated.—If a taper be burnt within the gas-jar, and fresh air be excluded from below by placing it upon a plate filled with water, it will be extinguished as soon as the oxygen of the air is consumed. A part of it will be found to have assumed the form of water, another that of carbonic acid, by uniting respectively with the hydrogen and oxygen

of the candle. The water may be seen; the carbonic acid may be detected by lime-water. Combustion and respiration are therefore very similar in their results.

4. To prove that pure carbonic acid does extinguish light, and precipitate lime.—A small Woulfe's bottle, with gas-delivery tube and safety-funnel, which may be purchased for two shillings, and which will be found very useful for other experiments, must be procured. Put into the bottle a few broken fragments of white marble, pour a little water over them, replace the safety-funnel, and, having seen that its straight tube just dips under water, pour half-an-ounce of spirits of salt or hydrochloric acid down it. Effervescence arises from the escape of carbonic acid, which begins immediately to pour out of the delivery-tube. If the latter be dipped into a wine-glass full of lime-water, the whole of the lime is quickly precipitated as white carbonate of lime, which will be redissolved, if the flow of the gas into the lime-water be continued. If the gas-jar be filled with this gas, by displacement of the water, its properties will be found to be a power of extinguishing flame and of precipitating lime-water. As the gas is poisonous, care should be taken not to inhale it freely.—Another instructive experiment is the weight of the gas. If the delivery-tube of the carbonic acid apparatus dip into an empty wine-glass, or, to speak cor-

rectly, into one filled with air, the carbonic acid will displace the air and fill the glass. If a lighted taper be placed in another wine-glass, the carbonic acid may be poured out upon it, and although it is invisible, its effects will be noticed by extinguishing the taper in the other glass.

5. To prove that germination is not dissimilar to respiration and combustion.—Take some mustard-seed, moisten them with a little water upon a cheese-plate, and place the stoppered gas-jar upon it, so as to enclose them. In three or four days they will have sprouted, and, on examination of the air, it will be found to extinguish a lighted taper and strongly to precipitate lime-water. And not only in this respect does germination resemble respiration and combustion, but in another also: it ceases in the absence of the oxygen. For seeds will not sprout at all in an artificial atmosphere of carbonic acid gas or of nitrogen. Oxygen is therefore essential to germination.

6. To prove that decay likewise alters the air.—If dying leaves be placed under a bell-glass, or the gas-jar, so that fresh air has no access, decay will not only cease as soon as the oxygen is consumed, but a lighted taper will be extinguished.

7. To prove that liquid water and ice only differ as regards latent heat.—Take any quantity of snow at the freezing point, and mix it with an equal weight of water at 172° ; the snow instantly melts,

and the temperature of the mixture is still only at 32°; here the water is cooled 140°, so that 140° of heat have disappeared altogether. Steam can only be considered as water combined with a greater amount of caloric; for, however long we boil water in an open vessel, we cannot make it in the smallest degree hotter than its boiling point. Prove this. Water, in being converted into steam, combines with more than five times the amount of caloric necessary to boil ice-cold water, and occupies a space 1,800 times greater.

8. To prove that all evaporation produces cold, owing to the fact just stated, that liquids require much heat to convert them into vapour.—Pour some ether upon your hand, drop by drop :—the sensation of cold will ultimately become painful. Repeated sprinkling of ether over the person would be as surely productive of death as freezing, for the evaporation of the ether would quickly carry off the life-heat of the body. Water thrown upon a fire acts in the same way; it becomes vaporized at the expense of the greater portion of heat which the fire contains.

9. To prove that when liquids become solid, heat is evolved.—Take a lump of quick-lime, and pour over it one-fourth of its weight of water, the latter will be absorbed, and yet the lime will remain dry. At the same time such intense heat is evolved, that it has been applied with success for culinary purposes.

The water in this case becomes solid, and the heat evolved in lime-slaking proceeds chiefly from the solidifying water.

10. To prove that flame requires a high temperature for its existence.—A cold substance placed in the flame of a candle causes a deposit of soot. Bring a mass of iron close to a flame, it will be extinguished on account of the conducting power of the metal.—Depress a piece of wire-gauze upon a gas-jet, you will find the flame will be cut off just where it touches the gauze; the inflammable matter of the flame passes through, but, in its passage through the gauze, is so far cooled as to be extinguished. Bring a piece of lighted paper to the upper side of the gauze, and the gas will be re-kindled. Vary the experiment. Place a piece of camphor, of the size of a pea, (and you may buy, with a penny, sufficient camphor for fifty such experiments,) upon the gauze, (which may cost three-pence,) and heat it below; the camphor will burn *below* with a bright white flame, yet, so great is the cooling power of the gauze, that, notwithstanding the volatile nature of camphor, it does not take fire on the spot where it lies.—Remark how often the gases which ascend from a dull fire, and are rendered visible by slight admixture with smoke, become enkindled, when a well-directed thrust with the poker introduces them into more immediate contact with heated embers and with air.

**PART III.—EXPERIMENTS EASY OF PERFORMANCE,
BUT ATTENDED WITH EXPENSE, AND REQUIRING
CARE.**

1. To study the character of *oxygen* unmixed with other gases.—Take 100 grains of chlorate of potassa, and mix carefully with 30 grains or thereabouts of black oxide of manganese. Put the mixture into a clean Florence flask, the mouth of which is connected by means of a cork with a gas-delivery tube, and apply gentle heat. As it is convenient to fill several bottles before experimenting, it is advisable either to buy a *pneumatic trough*,—(a vessel for collecting gases or airs, from *πνεῦμα*, *pneuma*, air or spirit); or to make some simple arrangement that will answer the same purpose. The following contrivance will answer. Make a shelf out of tin-plate, some inches broad, and so long that it will rest about half way up the sloping walls of the basin in which it is to be placed; bore a small hole through the centre of the shelf. When wanted for use, pour into the vessel as much water as will be sufficient to cover the shelf an inch deep, and then invert the vessel intended for the reception of the gas, with its mouth exactly over the opening, placing the extremity of the glass-tube, from which the gas proceeds, directly beneath, so that the gas may enter it as through a funnel.

Reject the first portion of gas, as it consists chiefly of expanded air, and contains but little oxygen. 100 grains of the chlorate yield 40 grains of oxygen, or about 3 imperial pints; it parts, in fact, with the whole of its oxygen, and is changed into chloride of potassium.—Introduce a glowing taper into the gas, it instantly bursts into flame, and burns with far greater brilliancy than in common air; the oxygen is consumed by combining with the carbon and hydrogen of the wax.—Into another jar introduce a small piece of red-hot charcoal, attached to a piece of copper wire; it bursts into flame, and burns with bright scintillations; carbonic acid is formed, the presence of which may be detected by agitation with lime water.—Into another jar introduce a piece of phosphorus, of the size of a pea, which may be most conveniently placed in a deflagrating spoon; inflame it inside the jar, *in the gas*, by means of a red-hot wire; it burns with inconceivable brightness, and affords a good illustration of the necessity of a heated solid substance for the production of a bright light. The snow-like substance which forms is phosphoric acid, which, however, is so soluble in water, that it soon disappears from the walls of the jars. The acid produced is very sour, and strongly reddens litmus.—Repeat the experiment in another jar with a spiral coil of watchspring, split up at the end, and tipped with melted sulphur; inflame the sulphur, and in-

troduce the wire into the jar. As the steel becomes red-hot, it combines with the oxygen, forming black oxide, fused balls of which, in a state of white heat, drop to the bottom, and melt into the plate upon which the jar is placed.

2. To study the character of *hydrogen*.—Boil some water in a kettle for a quarter of an hour, so as to expel all air: let it cool, and then carefully fill a test-tube and a small basin with the water; close the test-tube with the finger, and then invert it under the water in the bowl. Then press a piece of sodium, of the size of a pea, on to a piece of wire, and introduce it *quickly* into the tube, just under water; the metal leaves the wire, rises up in the tube, and decomposes the water; its oxygen unites with the sodium to soda, which dissolves, while its hydrogen is set free with effervescence. The tube is filled with a colorless gas, which *burns* with a pale blue flame on the application of a light,—water being the result of the combustion.—Put half-an-ounce of granulated zinc into a Woulfe's bottle, supplied with safety-funnel and gas-delivery tube, cover it with four ounces of water, and add, by degrees, about three quarters of an ounce of oil of vitriol. Effervescence ensues, which is much increased by the heat produced by the union of the sulphuric acid with the water, and the hydrogen may be collected in the same manner as other gases which are insoluble in water. One precaution is *very*

needful,* never to collect the gas until the air in the Woulfe's bottle has been entirely expelled. It is, therefore, the safest plan to reject the first pint of gas which passes over. Hydrogen is an inflammable gas, but not a supporter of combustion; a lighted taper introduced into the gas is extinguished, but the hydrogen itself, in contact with air, burns with flame. Observe, too, the deposit of dew in the jar after combustion, which is the water formed by the combination of the hydrogen with oxygen. Mark its lightness; you will find it impossible to preserve it in an open jar for upwards of a few seconds.—On account of its lightness, it is used for filling small balloons.—Fill a soda-water bottle with water, invert it in the trough and displace it with two-thirds hydrogen and one-third oxygen, and apply a light: the gases unite with explosion, and water is formed.

3. To study the nature of *nitrogen*.—Place a gas-jar upon a soup-plate filled with water. Fit its mouth with a cork, and slip the wire of the deflagrating spoon through it, so that the bowl of the spoon may be about the middle of the jar. Now take a piece of dry phosphorus, place it in the bowl, set fire to it *in* the jar by means of a red-hot wire,

* It is to prevent danger that I have advised caution: strong bottles with narrow apertures have been fractured by the approach of a light, and much mischief resulted. The experiment, however, may be safely performed as just described.

screw the cork in, and leave it for ten minutes. (The phosphorus will burn as long as oxygen is contained in the air of the jar, the water will rise and occupy one-fifth of the internal space, and will dissolve the white vapor of phosphoric acid). The colorless, transparent gas remaining in the jar is nitrogen, and will be found to be a non-supporter of combustion, as it *extinguishes a lighted taper*.

4. To study the nature of *ammoniacal gas*, a chemical compound of nitrogen and hydrogen. As water is capable of dissolving 680 volumes of this gas, it is impossible to collect it over water. But many of its properties may be best studied in the solutions of the gas, sold in the shops as caustic ammonia. It is possessed of a most pungent taste and smell, and, under various forms, is much used by ladies, as smelling salts, sal-volatile, &c. It blues reddened litmus-paper, and turns turmeric-paper brown. The gas is much lighter than air, and may be easily obtained by boiling the ammoniacal liquid. For this purpose a Florence flask is best employed, into which pour half-an-ounce of strong caustic ammonia. Instead of employing a gas-delivery tube, place a straight tube in the perforated cork, and apply heat. Wide-mouthed bottles must be used to collect the gas, and these are so held as to admit the tube; the gas rises and displaces the air so quickly, that several pint bottles may be filled in a minute. When three bottles have been filled, pro-

ceed as follows:—Remove the stopper from one of the bottles, close the mouth with a piece of glass, and invert it under water; the most rapid absorption takes place, and the bottle becomes filled with a very dilute solution of ammonia. In another bottle the flame of a lighted taper is extinguished, and the gas itself burns momentarily with a pale green flame.—Test the liquid formed by shaking a bottle of gas with an ounce of water, with turmeric and litmus paper. (Be very careful not to squirt any ammoniacal liquid into the eye.)

5. The properties of *potassium*, the basis of potash, are sufficiently striking, and may be easily studied.—A small piece, of the weight of a grain, will suffice. It may be cut with a penknife, and then exhibits a silver-white surface, which immediately tarnishes by attracting the oxygen of the air. Its affinity for oxygen is so great, that it must be kept under Persian naphtha, a compound of carbon and hydrogen. A small piece of the metal thrown into a few drops of water in a saucer, bursts into flame, is carried rapidly about, and is quickly dissolved. The water is decomposed; its oxygen unites with the potassium and dissolves, whilst its hydrogen is inflamed by the heat of the combustion, and burns with a violet flame—the color being due to admixture with a little volatilized potash. The remaining water will be found on examination to possess a caustic (burning) taste, and to blue red-

dened litmus paper. On evaporation caustic potash is left, a white substance, which, by attracting moisture from the air, deliquesces and forms a liquid. Caustic potash is a combination of potassium, oxygen, and water. Its affinity for carbonic acid is as great as that of the metal for oxygen, or of the oxide for water. On exposure to the air for a few hours, it will be found to effervesce on the addition of a few drops of vinegar, a property not possessed by the oxide.—Carbonate of potash may be prepared from a stick of wood, by burning it and dissolving the white or grey ash in a little water. The filtered solution will be found to effervesce with acids, to possess a caustic taste, and to blue reddened litmus. On evaporation, a white carbonate remains, which quickly attracts water, and deliquesces. From the carbonate of potash of the shops, caustic potash is prepared, as described at page 189. Potash and its salts are exceedingly useful. Glass and soft soap contain it. If sand be boiled some hours with strong caustic potash, some of it is dissolved, and a silicate of potash is obtained. For fats it has the very strongest affinity. A piece of rag soaked in oil is completely freed from it by boiling in potash, as the student may discover by experiment.

6. The properties of *sodium* and of *soda* are not very dissimilar from those of potassium and potash, yet are the differences sufficiently striking.—Sodium

is a whiter metal, and does not burn on cold water, although the action is nearly as vehement, and the solution of the soda as rapid. Soda communicates a yellow color to flame, as may be seen by throwing a grain of the metal into boiling water. The salts of soda effloresce, by giving off water of crystallization.

7. *Lime* is the *oxide of calcium*.—It may be prepared by heating a chip of marble in a bright fire. It is white, and easily pulverized. It is caustic, and destroys the paper or linen in which a piece may be wrapped by way of experiment. A few drops of water poured upon quicklime are immediately absorbed; abundant heat results, and a fine powder, slaked lime, is produced. Hydrate of lime, or slaked lime, dissolves sparingly in water, to which it communicates alkaline properties, and the lime-water thus formed quickly attracts carbonic acid. It must therefore be kept in well-stoppered bottles, and is useful for the detection of carbonic acid, with which it forms a white powder, carbonate of lime or chalk.

8. *Alumina*, or the *base* of clay, may be easily obtained from alum. It falls from a solution of alum, on addition of ammonia, in form of a thick colorless jelly. It is thrown upon a filter, and washed well with water. When dry, it is a white powder, insoluble in water, and therefore perfectly tasteless. It adheres to the tongue, and is soluble

in acids and alkalies. When heated to redness, it loses its water of combination, and becomes converted into alumina. It is then insoluble in acids and alkalies. Next to silex, alumina is the chief constituent of soils.

9. *Iron-rust*, or the *red oxide of iron*, contains the same quantity of oxygen as alumina, which, in many respects, it resembles. On the addition of ammonia to the perchloride of iron, the red oxide precipitates in the form of a brownish-red flocculent jelly. By dissolving iron in warm nitric acid, its properties may be further studied. Carbonate of soda throws it down from its salts as hydrated peroxide of iron; during the operation, the carbonic acid escapes with effervescence, as it does not enter into combination. When heated to redness, the hydrate loses its water, and the red oxide resulting is only slightly soluble in acids. Peroxide of iron is very abundant. It is contained in flesh and blood, in vegetables, and in bread. Dissolve the ash from a piece of burnt meat in spirits of salt, (hydrochloric acid), filter, and add ammonia; hydrate of the red oxide will be precipitated. Yellow prussiate of potash detects minute traces, by exhibiting a beautiful blue color, when added to the solution containing iron. Tannin, or the yellow mass found in gall-apples, is likewise a good test. Ink is a per-tannate of iron, and may be prepared by adding tannin to a persalt of iron. A black ink may be

made by boiling two and a half ounces powdered nut-galls in thirty ounces of water, for a quarter of an hour. Filter and dissolve in it, in an *open* vessel, one ounce of gum and one ounce of green vitriol (proto-sulphate of iron). When it is dark blue, it may be bottled for use. Green vitriol is a proto-sulphate of iron, as stated at p. 237. The attraction of prot-oxide of iron for more oxygen is so great, that it is impossible to preserve it pure. On addition of ammonia to a solution of proto-sulphate, the originally white precipitate immediately becomes green, and passes through every possible shade, till it becomes at last converted into the hydrated red oxide of iron. The metal iron dissolves with ease in weak sulphuric, nitric, and hydrochloric acids. Hydrogen is given off when sulphuric or hydrochloric acids are employed.—A piece of steel may be easily distinguished from one of iron; for, if a drop of nitric acid be let fall upon it, it will occasion a black spot, but will have no such effect upon wrought-iron. Again, when steel is dissolved in nitric acid, charcoal will indicate itself by its characteristic black color. An iron wire only one-tenth of an inch in diameter will carry 150 lbs. without breaking.

10. The presence of *copper* in an ore may be easily discovered. Boil a piece with a little nitric acid, dilute with water and filter. If a nail be now placed in the filtered solution, (which, if copper be

present, will probably be of a blue color), the copper will be precipitated upon the nail in its natural color.—Copper-wire of one-tenth of an inch in diameter will support a weight of 300 lbs.—Expose a piece of copper, moistened with vinegar, to the air, it will soon be covered with verdigris.—The ordinary oxide of copper is that which is obtained by dissolving the metal in acids.—Ammonia throws down the hydrated oxide of copper from its solution in form of a bluish-white precipitate, which redissolves when excess of ammonia is added, giving rise to a deep purple liquid.—Yellow prussiate of potash is an excellent test of the presence of copper, with which it forms a red-brown precipitate.

11. *Lead* dissolves easily in nitric acid, and forms a beautiful white salt. From the nitrate thus resulting, or from a solution of sugar of lead, (acetate of lead) the properties of prot-oxide of lead may be conveniently studied.—Spirits of salt throws down white chloride of lead from such solutions.—Sulphuric acid precipitates insoluble white sulphate of lead.—Ammonia, potash, and soda, throw down white oxide of lead. When lead is melted in an iron ladle, a scum is soon formed, which is the ordinary prot-oxide of lead.—By continuing the heating of the yellow oxide in a reverberatory furnace, it can be made to take up more oxygen, and become changed into red oxide of lead.—Of this, take one quarter of an ounce and

mix it with a few grains of charcoal; fill the bowl of a tobacco-pipe with it, place this in the middle of a common fire, and soon the lead may be poured out in the metallic form. In this process the carbon combines with the oxygen of the red-lead to carbonic oxide, and the lead is reduced.

12. The metal *zinc* has more powerful affinities than lead, so that if a piece of zinc be suspended in a solution of sugar of lead, a solution of acetate of zinc is obtained, whilst the lead is thrown down in the form of a so-called lead tree. Indeed, zinc has so great an affinity for oxygen, and its salts are so permanent, that none of the ordinary metals will precipitate it from its solution in the metallic form.—Ammonia throws down the hydrated oxide of zinc, of a white color, from its solutions; excess of ammonia re-dissolves it.—Zinc, if beaten out in thin leaves, will take fire from the flame of a candle. In the fire, the combustion of zinc is most beautiful.—Zinc dissolves in weak sulphuric acid with effervescence; sulphate of zinc is formed, and hydrogen is set free.

13. *Tin* is one of the lightest of the metals, and so soft and ductile, that it may be beaten out into leaves thinner than paper.—It emits smell when rubbed.—If tin be heated in strong nitric acid, the whole of the metal will be converted into a white powder, which is a hydrate of the peroxide; but if this be heated so as to drive off the water, it

assumes a yellow color, and is then the peroxide of tin.

Further experiments might be suggested; but if those which have been described above should give a taste for Chemistry, other books will be searched with advantage by the young student.

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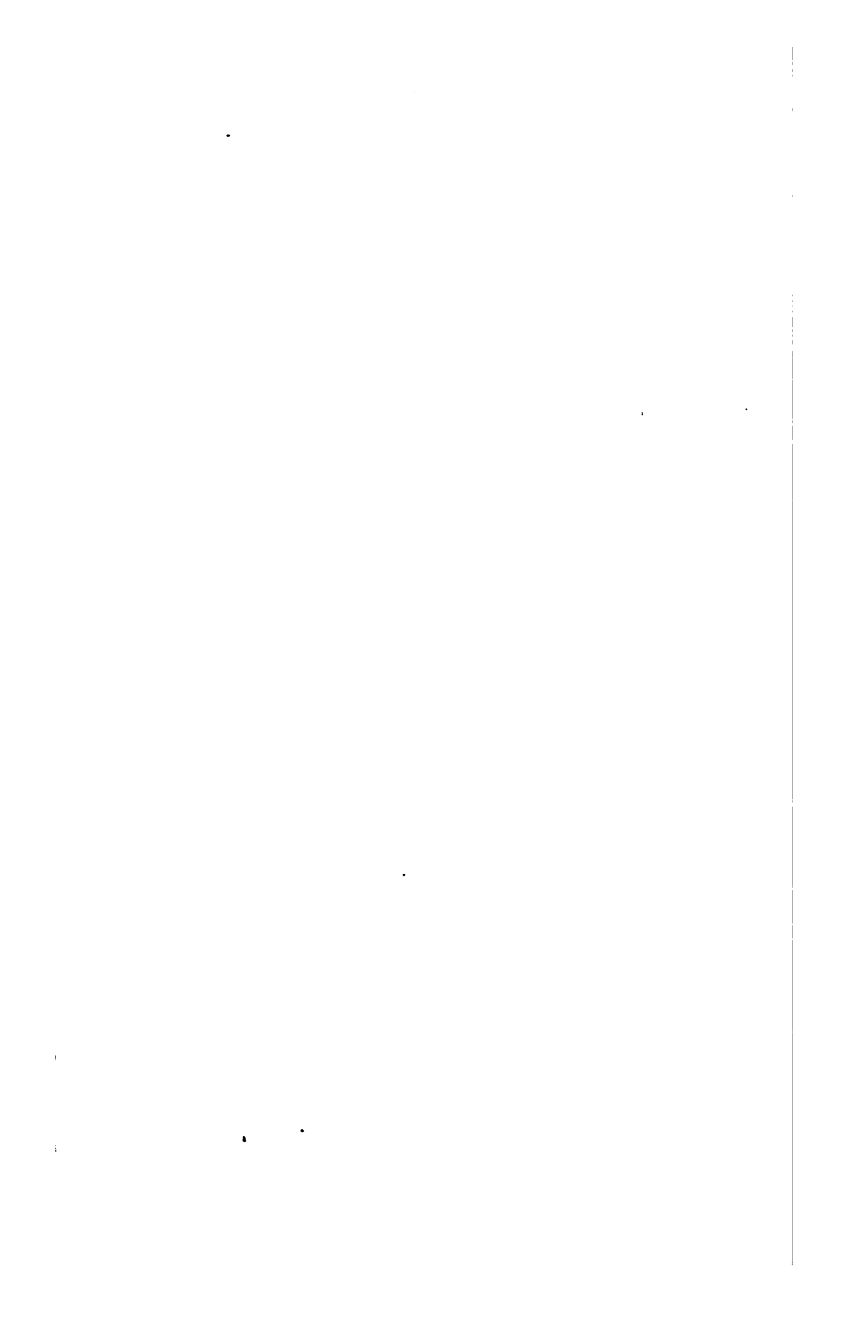
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